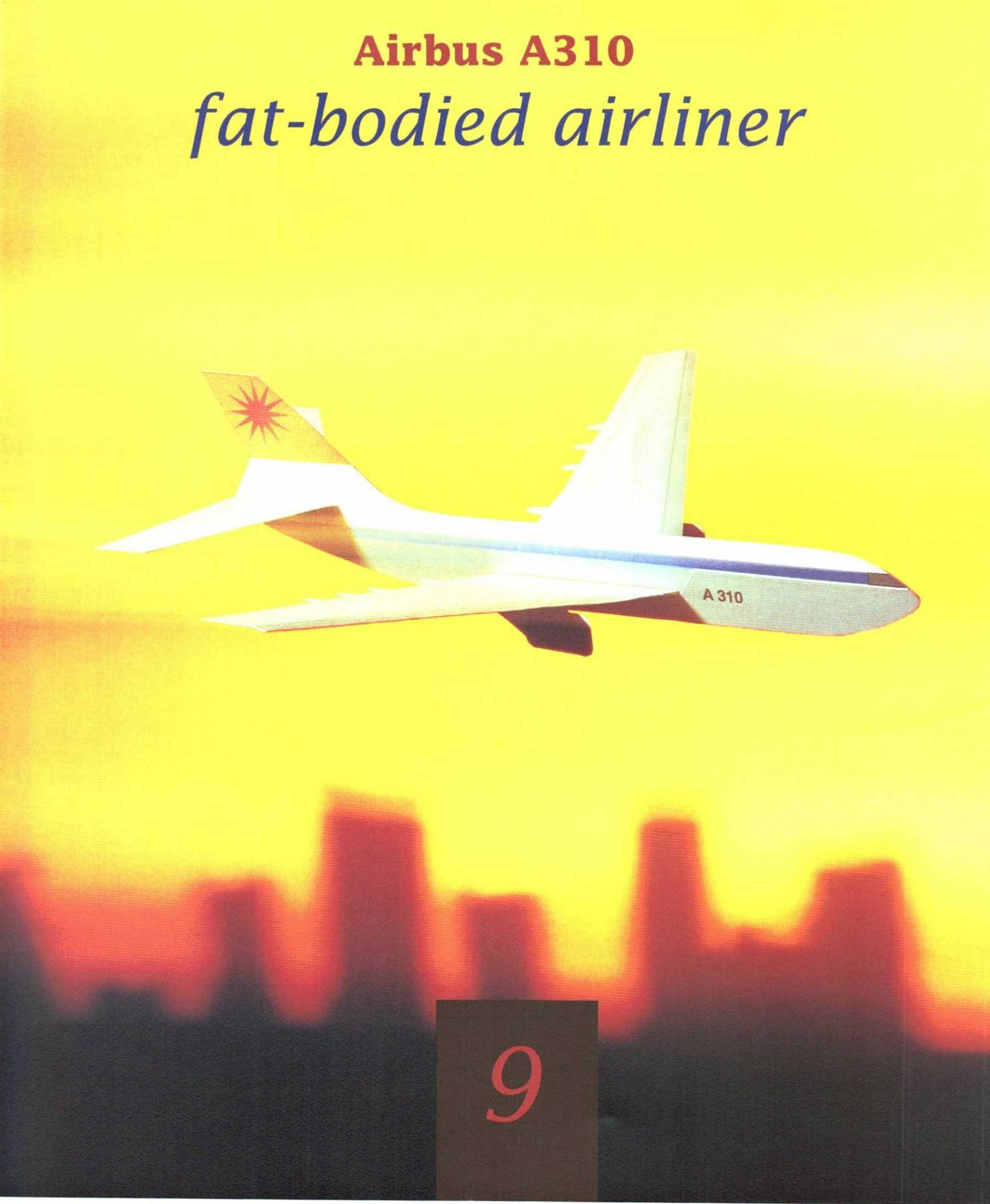
Airbus A310

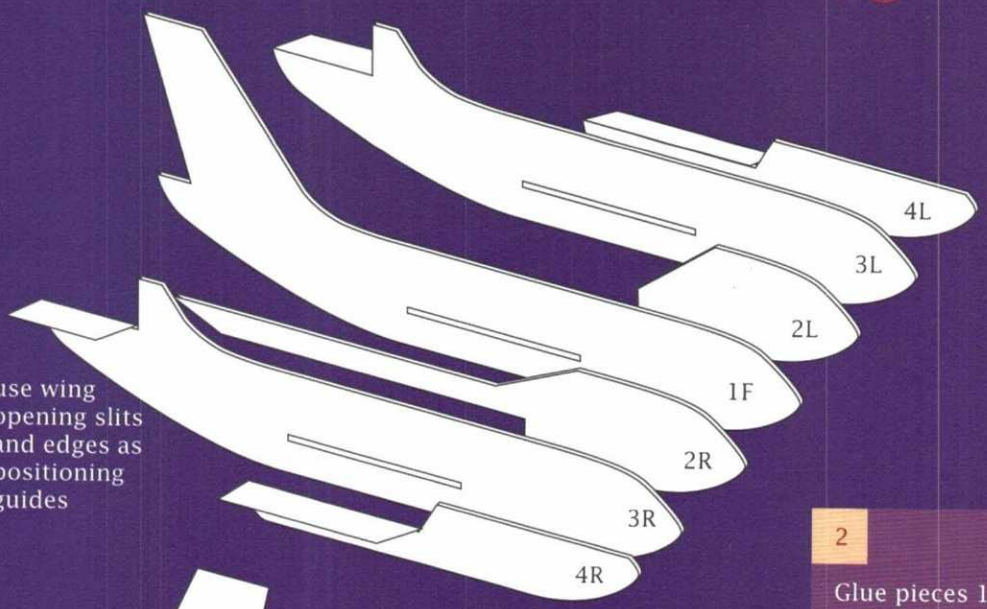
fat-bodied airliner



Building the Airbus

1

Photocopy the parts layouts for this model. Then cut out and prepare the pieces. (See the general instructions beginning on p 4.)



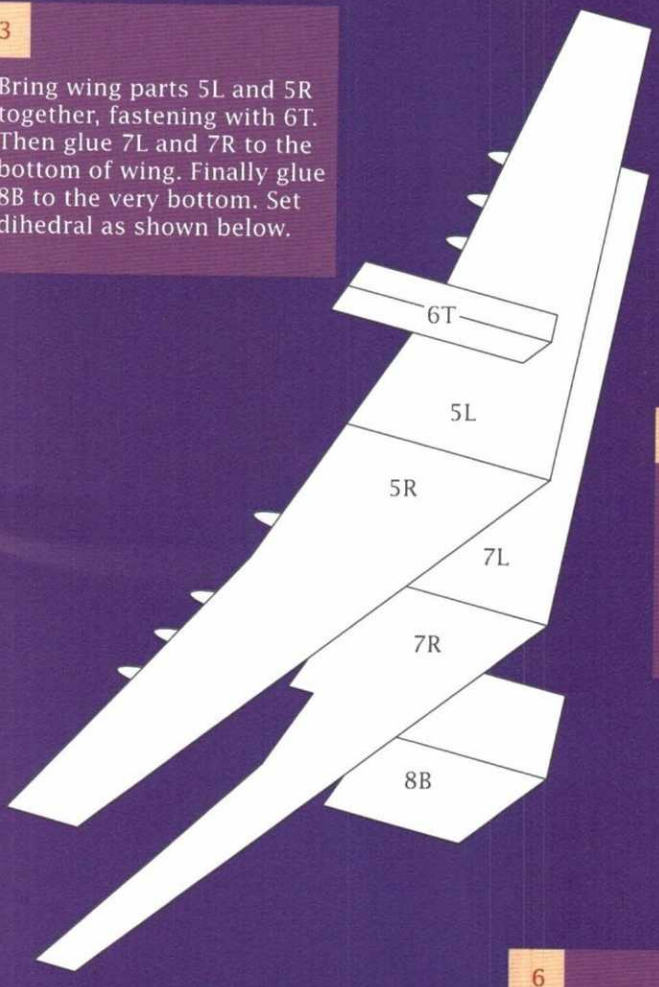
use wing opening slits and edges as positioning guides

2

Glue pieces 1F through 4R and 4L to build up fuselage layers, carefully aligning parts.

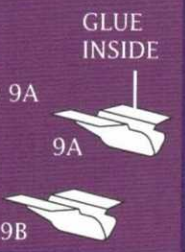
3

Bring wing parts 5L and 5R together, fastening with 6T. Then glue 7L and 7R to the bottom of wing. Finally glue 8B to the very bottom. Set dihedral as shown below.



4

Glue the two engine pieces 9A and 9B, as shown.



5

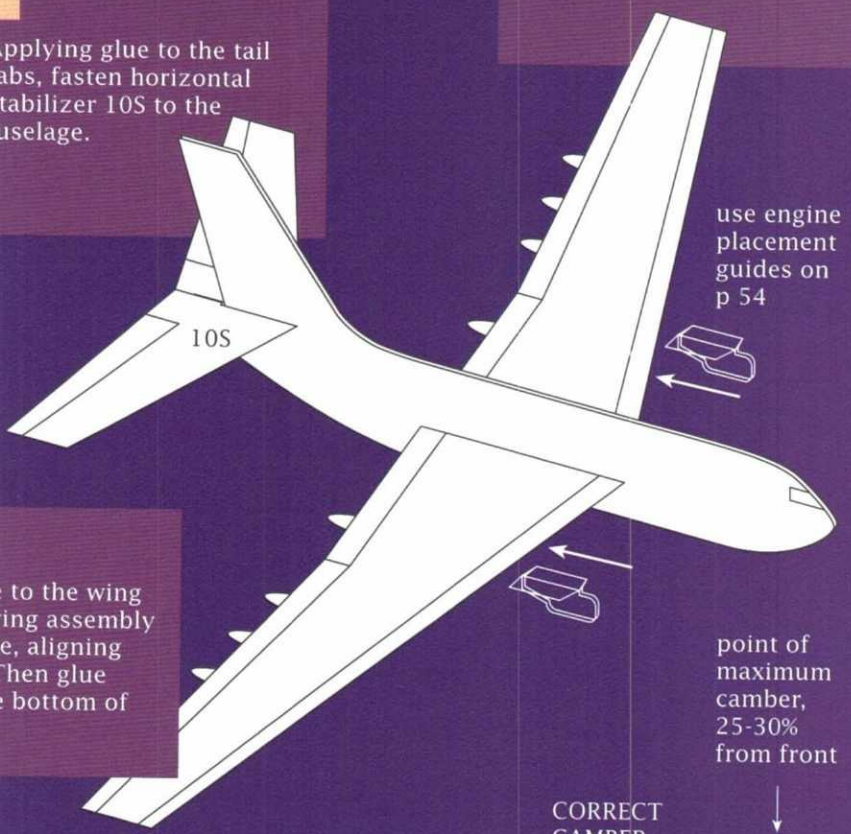
Applying glue to the tail tabs, fasten horizontal stabilizer 10S to the fuselage.

6

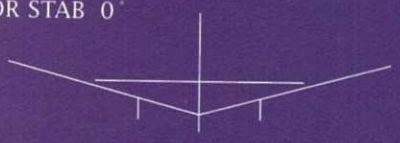
Applying glue to the wing tabs, fasten wing assembly to the fuselage, aligning center lines. Then glue engines to the bottom of wings.

7

Camber the wings by curving the paper gently between thumb and forefinger. See below.



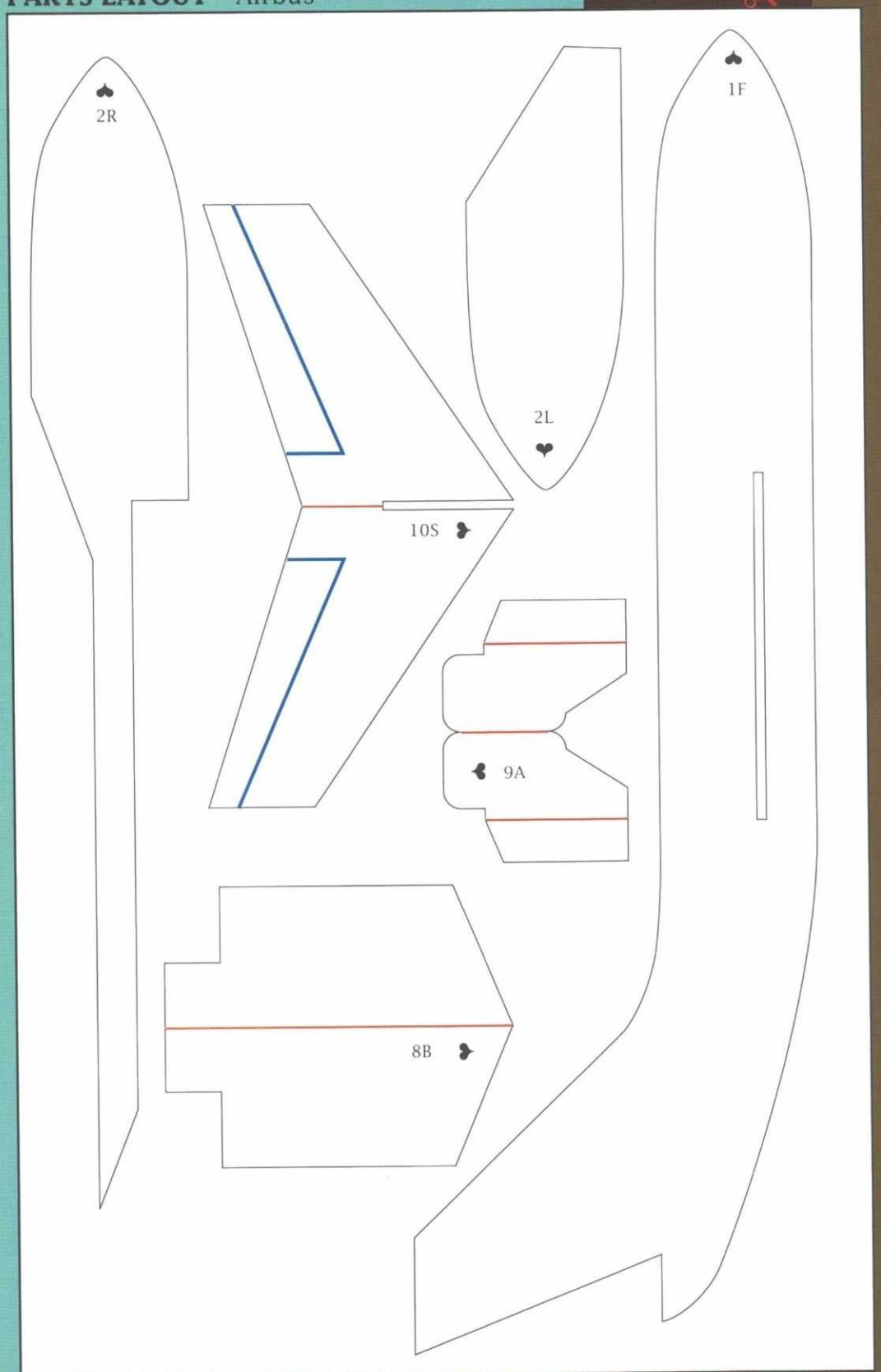
WINGS 12°
HOR STAB 0°



NOTE
- Cut on lines shown in black.
- Score lines in red.
- Use the blue lines as guides for adding details to the plane.
- Indicates the front edge of the piece.

NOTE
CUT OUT PHOTOCOPY ONLY

PARTS LAYOUT – Airbus



jet transportation

Although all jets are powerful, not all are meant to go supersonic, and not all are fighters. Transport airplane performance had followed military airplane performance since the beginning of flight by the Wright brothers. And now, because of the efficiency of jet propulsion, jet engines were used in many different kinds of subsonic transport planes. During the 1950s airports everywhere increasingly displayed a variety of them.

When prosperity returned in the 1950s an increasing number of people traveled by air. Large piston driven four-engined airliners, modeled on wartime heavy bombers, were built to accommodate them. At 300 miles per hour, a plane flying from New York to Los Angeles could complete the trip the same day. Even Europe was available with next-day arrival times. These airliners proved that passengers could be carried safely for great distances at high speed and at an altitude above the turbulence of weather. Pressurized cabins provided the comfort of ground-level breathing in the thin air of high altitude. With these American-built planes, airlines established worldwide routes and set the stage for jet powered transportation.

Not to be outdone by American companies, the British took the next step. In 1952, on

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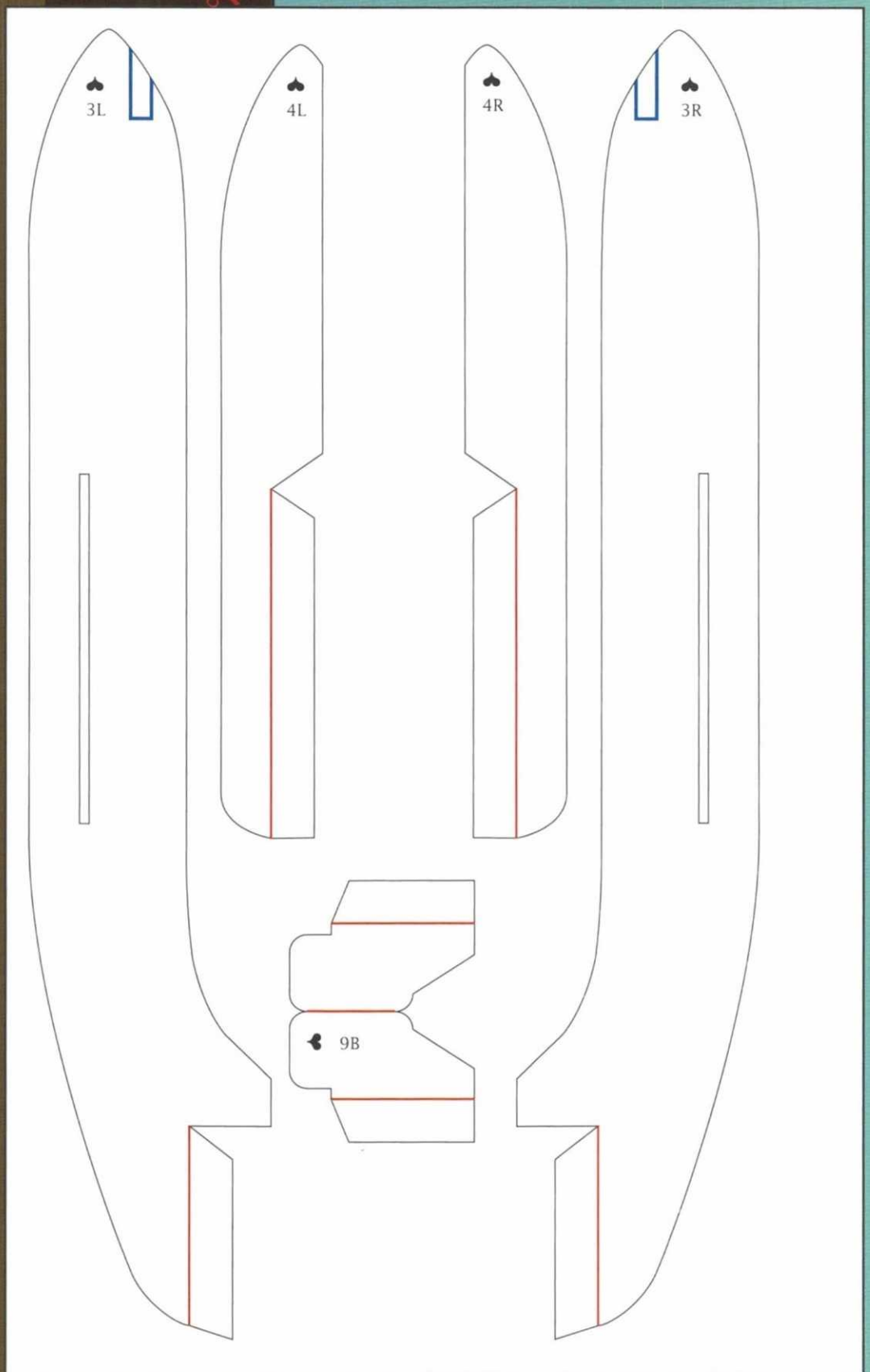
PARTS LAYOUT – Airbus



the London-to-Johannesburg route, a new sleek airliner was introduced, the de Havilland DH-106 Comet. **(#6, p 34.)** It was a sensation. This airliner provided non-stop, quiet, comfortable, 500-miles-per-hour-service at 40,000 feet. However, Britain's first step into jet transportation came at a high price.

With its four turbojet engines hidden in the gracefully swept wings, the smooth-skinned Comet had a promising futuristic look. Because it was nearly 200 miles per hour faster than its nearest competitor, as many as ten different airlines immediately ordered Comets. But in two short years the Comets were all grounded. Several had mysteriously broken up in midair, with great loss of life. The Comets' airframes could not withstand prolonged pressurization at high altitudes. They cracked around the windows and came apart.

All was not lost for the Comet, however, for it has come back into service as an entirely different airplane, the Nimrod. It is used by the Royal Airforce in long-range maritime patrol. The plane's electronic surveillance hardware and weaponry mask its once graceful lines. It is now one of the world's most advanced anti-submarine aircraft and will be in service well into the next century.

The Boeing company, known for its successful bombers, began experiments with jet engines in 1947. As did the Me 262,

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NOTE
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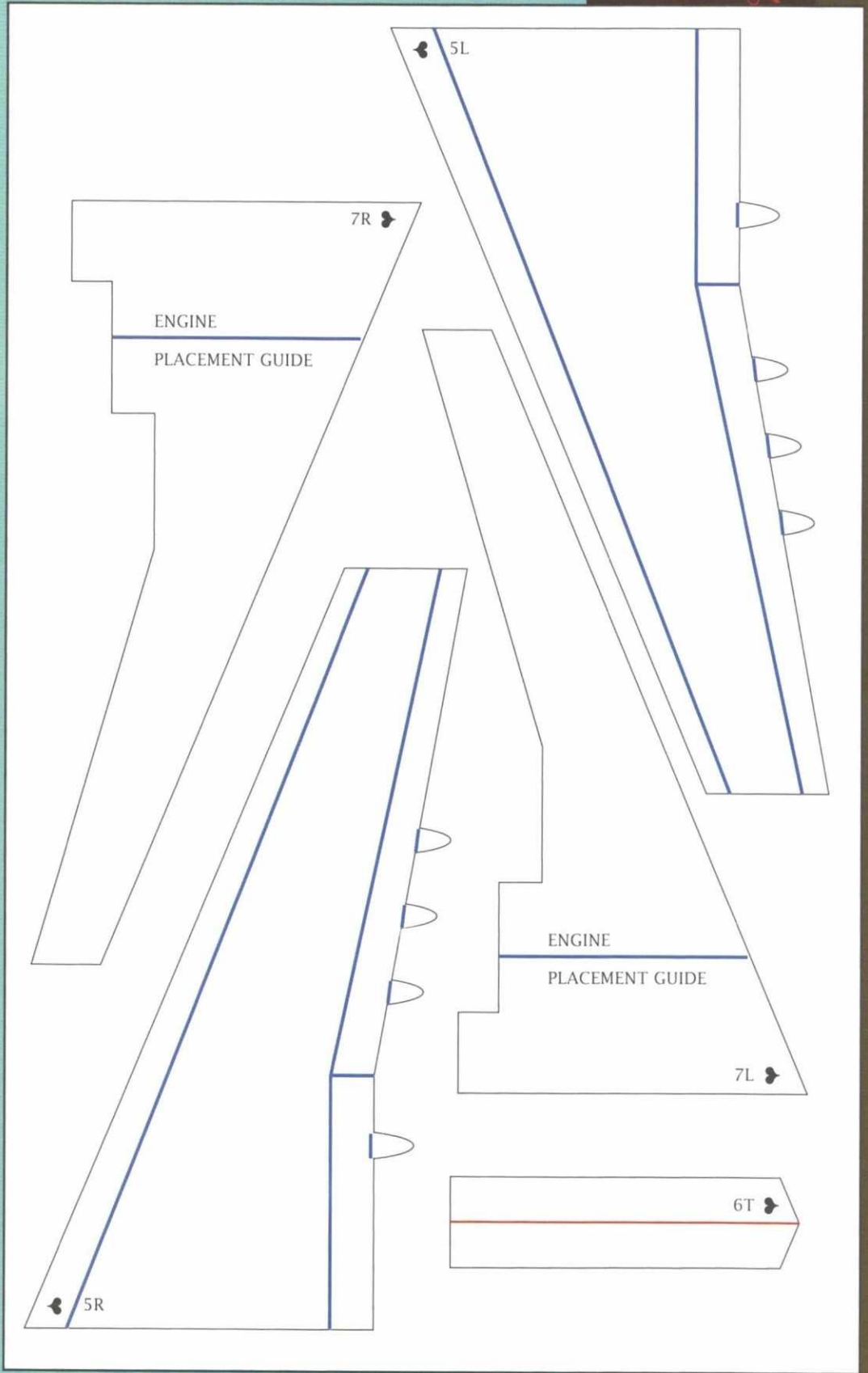
PARTS LAYOUT – Airbus



Boeing's planes had the engines suspended in pods beneath gracefully swept wings. With their experimental XB-47 bomber, they had discovered that this arrangement yielded extraordinary results for large airplanes. With its six podded jet engines spread along the wings, the XB-47 could fly 600 miles per hour at 45,000 feet, making it virtually immune from attack. This design, more than any other, inspired all future jet powered swept-wing transports.

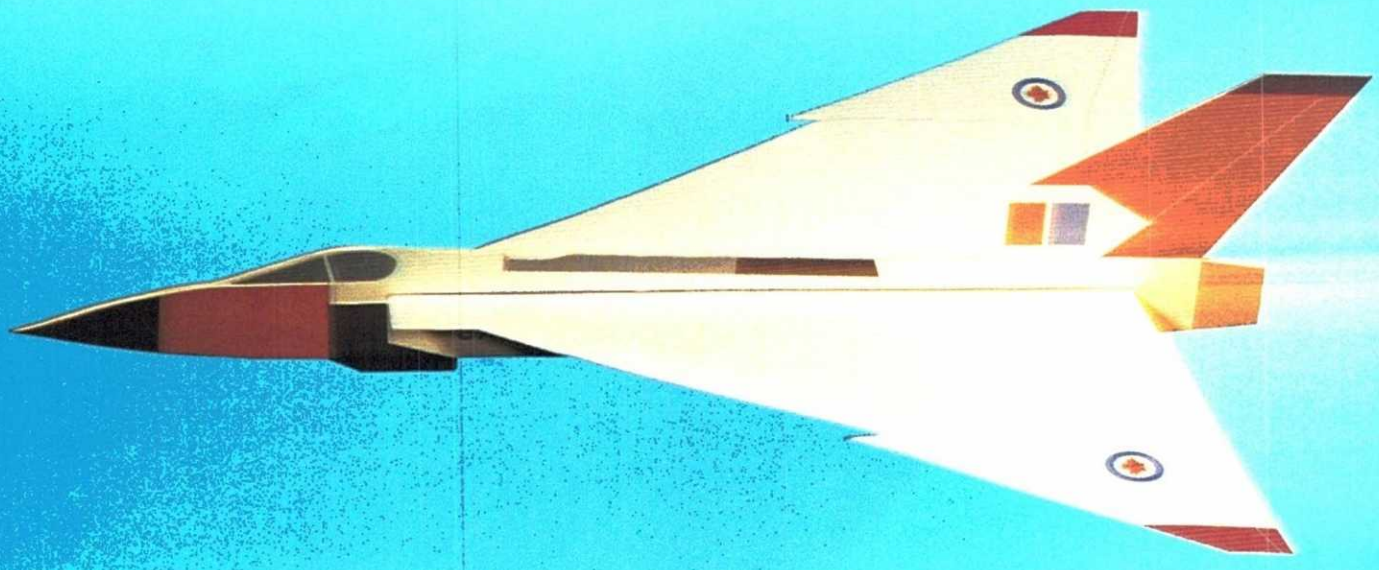
In 1954, just before the Comet airliner crashes, Boeing introduced the first American jet airliner, the 707. After the Comets were grounded, the Boeing 707, along with transports introduced by other manufacturers, such as the Douglas DC-8, took the lead as the world's airliners.

These airliners cruised at 550 miles per hour at 40,000 feet. They were quiet and comfortable, and brought great change to the fabric of society as they seriously challenged train and ship travel. Now, transcontinental and transoceanic flights became commonplace. Air travel was no longer just for the wealthy.

With these planes a standard was set that remains to this day. Although airliners today can fly at 625 miles per hour, they rarely do so in regular service. To go faster is to enter the transonic range where more power is required and fuel

Avro Arrow

futuristic fifties



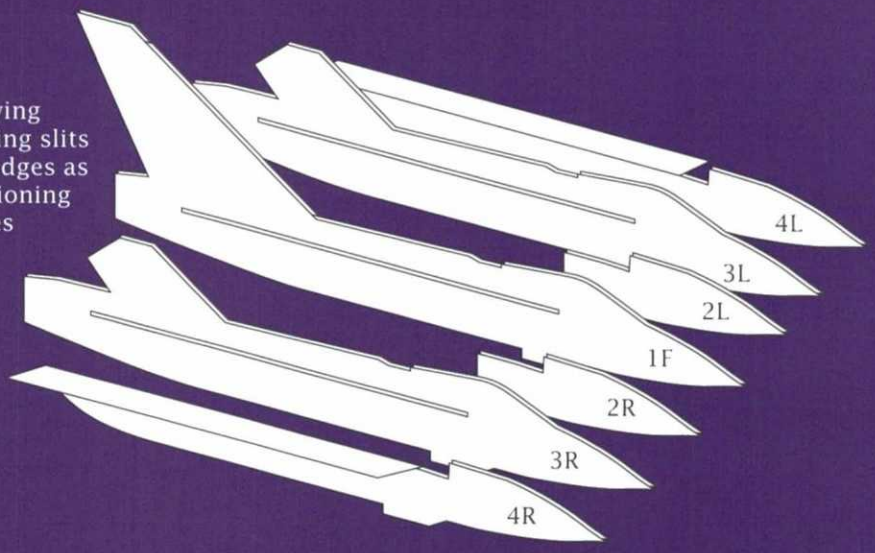
10

Building the Arrow

1

Photocopy the parts layouts for this model. Then cut out and prepare the pieces. (See the general instructions beginning on p 4.)

use wing opening slits and edges as positioning guides

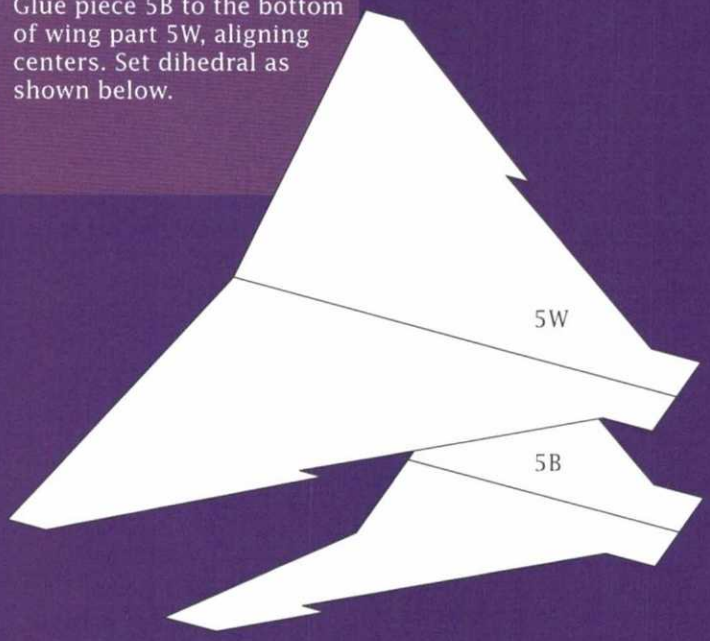


2

Glue pieces 1F through 4R and 4L to build up fuselage layers, carefully aligning parts.

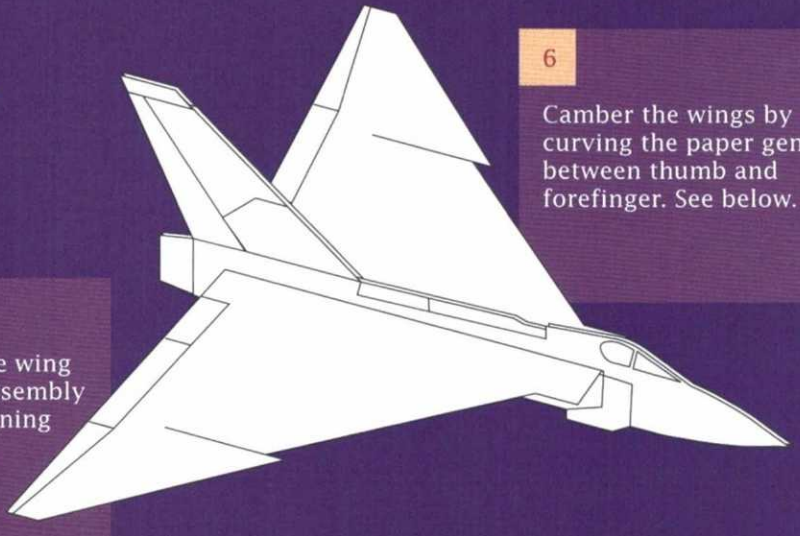
3

Glue piece 5B to the bottom of wing part 5W, aligning centers. Set dihedral as shown below.



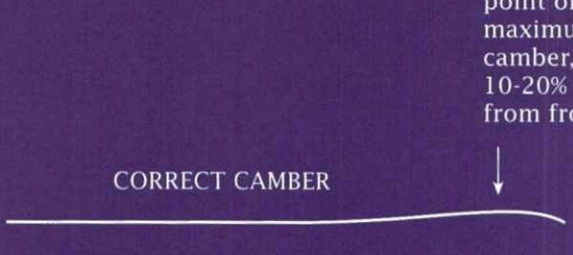
5

Applying glue to the wing tabs, fasten wing assembly to the fuselage, aligning center lines.



6

Camber the wings by curving the paper gently between thumb and forefinger. See below.



consumption increases sharply because of compressibility drag, and there are added stability problems. Taking into account the total time required for boarding, departure, and arrival procedures, airspeed would have to increase greatly in order to shorten travel time.

As the throng of passengers and loads of cargo increased, manufacturers ventured to build bigger and bigger transports instead of faster ones. One such giant is the Boeing 747 Jumbo, first seen by the public in 1968 as it entered service on long-haul passenger routes. **(#7, p 39.)** It is characterized by its wide body. Originally this design had been intended for military cargo transport, but Boeing lost the military contract to the Lockheed company and its design, the C5 Galaxy.

The 747 Jumbo carries almost 500 passengers. It is powered by four fanjet engines, (see p 79) which combine propeller and jet propulsion. They are more fuel efficient and operate more quietly than ordinary turbojets. With a nonstop range of nearly 7000 miles, the New York-to-Tokyo route, once a month-long ocean voyage or a five-day piston-powered air journey, became an overnight trip. The 747 is popular on many regular and holiday transoceanic charter routes. For many people it is their first jet encounter, as they go on family vacations.

NOTE
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- Score lines in red.
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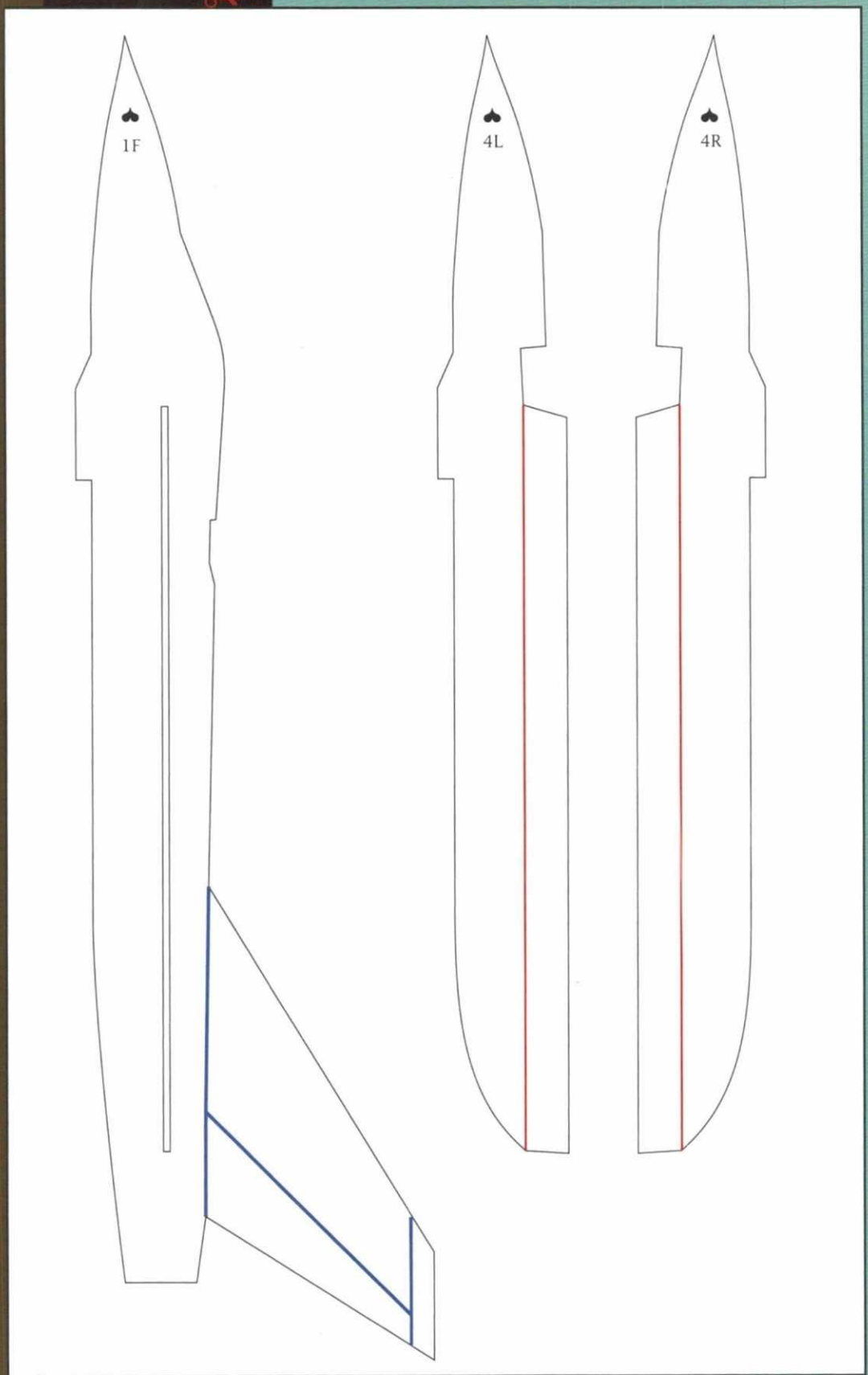
- ➧ Indicates the front edge of the piece.

NOTE
CUT OUT PHOTOCOPY ONLY

PARTS LAYOUT – Arrow



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NOTE
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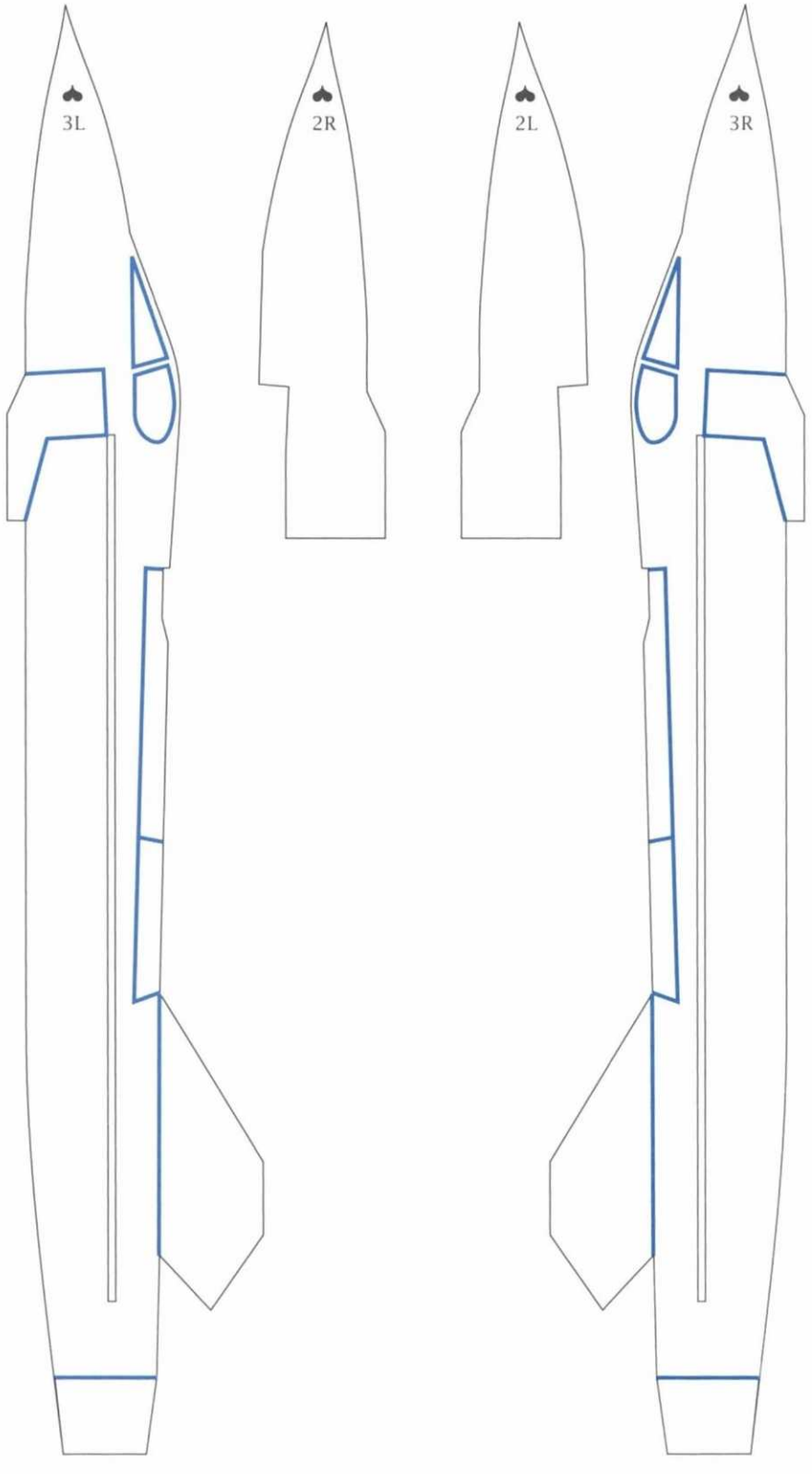
PARTS LAYOUT – Arrow



As businesses prospered in the 1950s, busy executives traveled the world. Their time was valuable and they demanded speedier flights. This need for speed affected the design of airliners, as the need for speed had fighters. Engineers began to investigate the possibility of supersonic transportation. Building any aircraft is a costly venture, which affects the cost of air travel. The goal was to reduce the time of air travel from Europe to North America to three hours, and make travel between any cities in the world a possibility within a twelve hour period, no matter the cost.

With this in mind, in 1962, British and French engineers collaborated to produce the Concorde. **(#8, p 45.)** Rolls-Royce developed engines with enough thrust to propel this airliner through the air at a sustained supersonic speed, which is known as *supercruise*. The Concorde is made of aluminum alloy, which has a thermal barrier of Mach 2, a speed that nicely fit the travel time objectives. Electronic devices aid the pilot to fly and navigate the airplane. This beautiful stiletto whisks its passengers across the ocean at twice the speed of sound in first class luxury. The plane's success, however, is limited, first by cost of this luxury, and second by the fact that it cannot go supersonic over populated areas because of the effects of the sonic boom.

By the 1970s ordinary travelers could travel easily to any city in the world. Unlike the business executive, however, they wanted to do it cheaply. This led to the design of an entirely different sort of airliner, the Airbus. **(# 9, p 50.)** The name alone suggests economy. This plane is a collaboration between France, Germany, Holland, Spain, Britain, and others.

The Airbus, a smaller wide-bodied airliner with 330 seats, economized in two ways. First, the way in which pilots controlled the plane had always been achieved through mechanical linkages between the cockpit and the control surfaces. Guages and other instruments were traditionally also mechanical. Advances in electronics and computers had occurred, in part, through lessons learned in building military planes. This gave designers enough confidence in computers to replace mechanical devices with electronic ones in passenger planes. This simplified the airplane and made it more economical to operate. Second, large jet airliners had usually had four engines, but with improvements in the power output and durability of fanjets, only two were used on the Airbus. This meant further economy.

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NOTE
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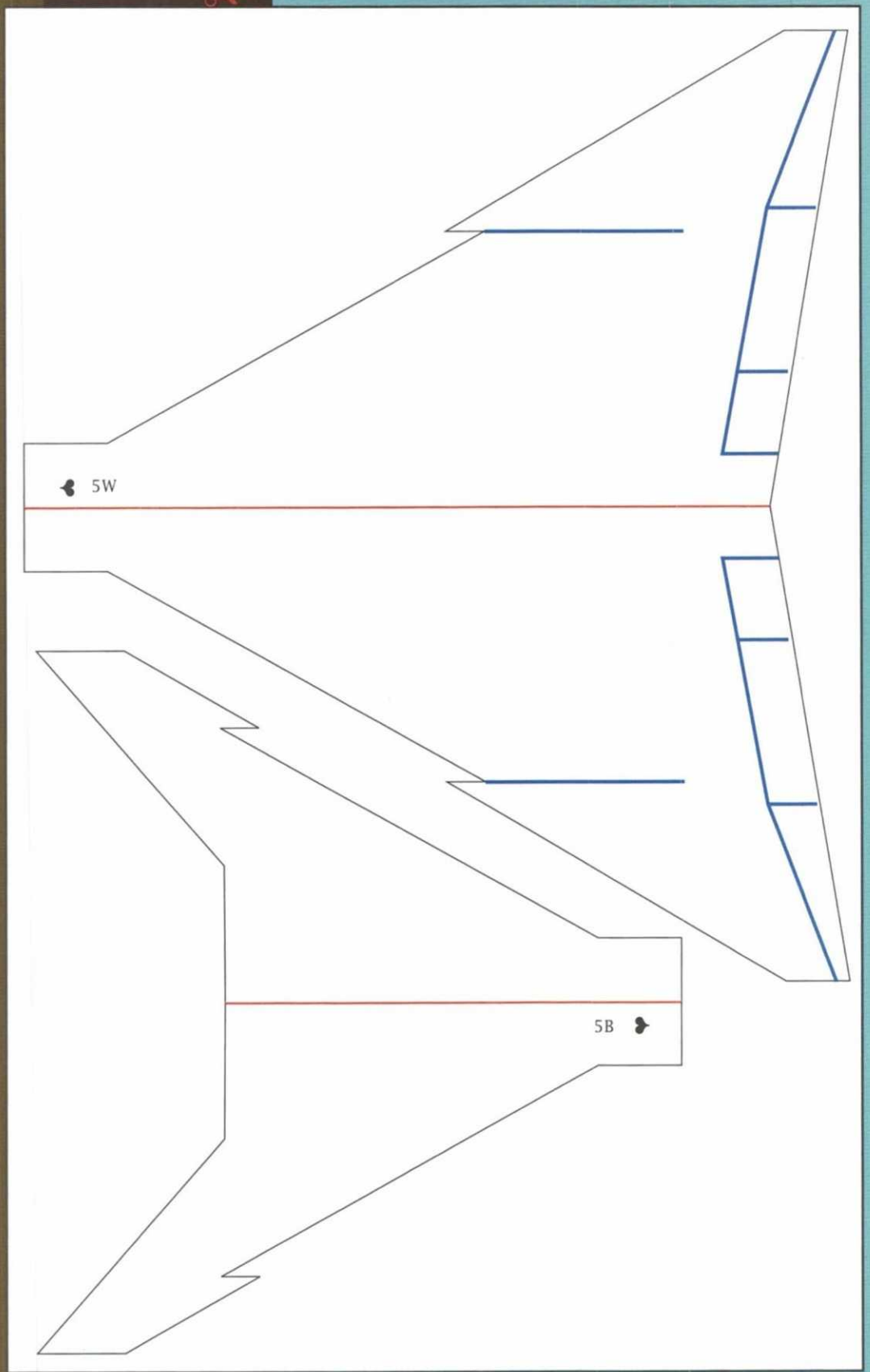
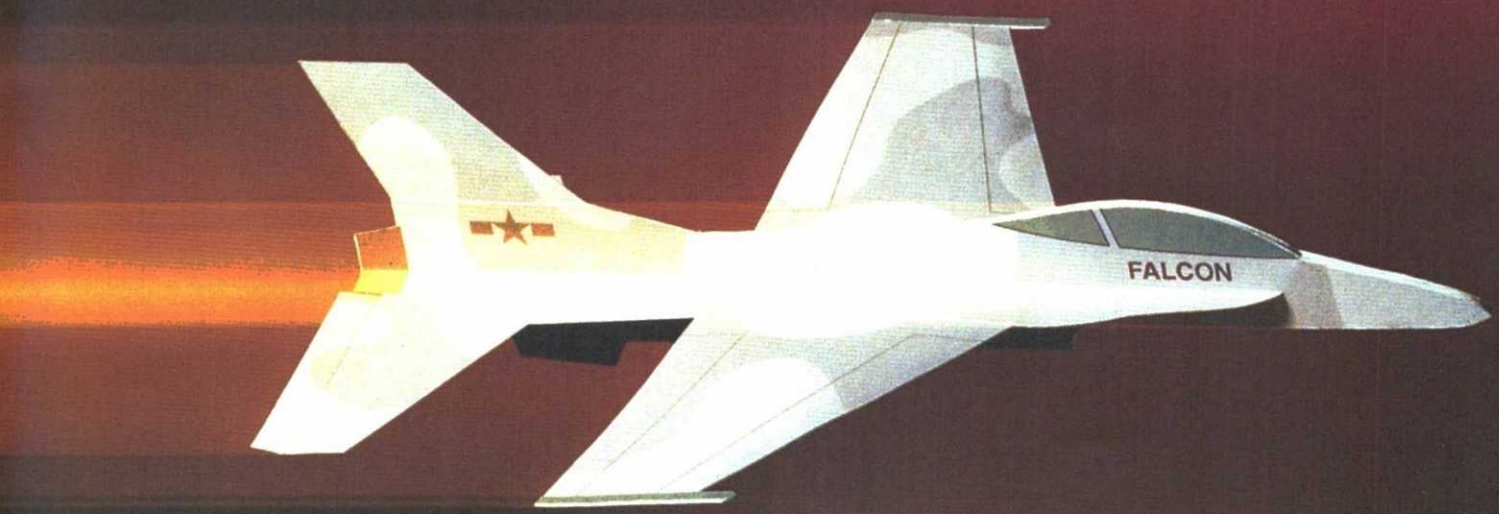
PARTS LAYOUT – Arrow



General Dynamics F-16 Falcon

airborne computer



11

Building the Falcon

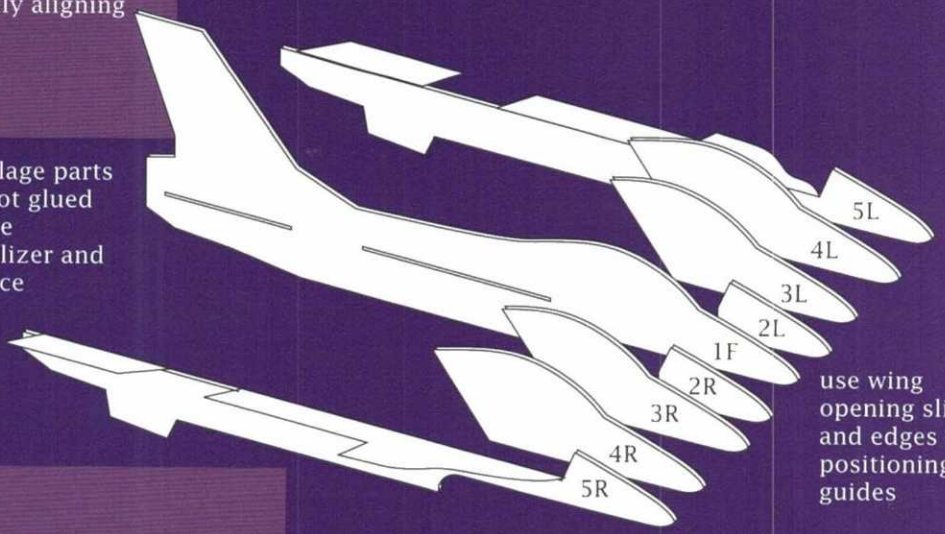
1

Photocopy the parts layouts for this model. Then cut out and prepare the pieces. (See the general instructions beginning on p 4.)

2

Glue pieces 1F through 5R and 5L to build up fuselage layers, carefully aligning parts.

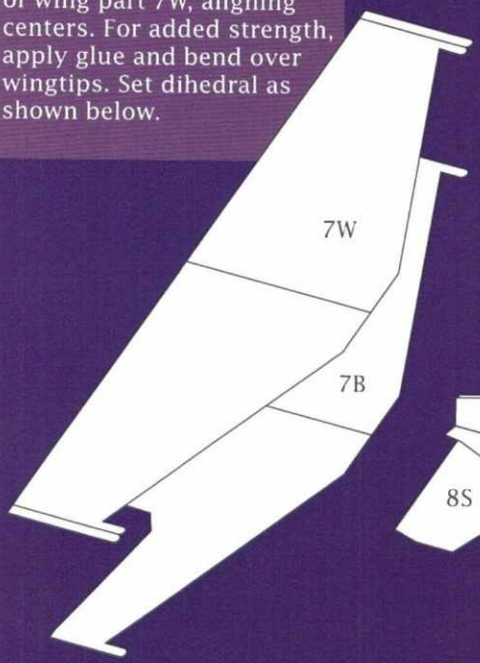
notice that fuselage parts 6L and 6R are not glued in place until the horizontal stabilizer and wings are in place



use wing opening slits and edges as positioning guides

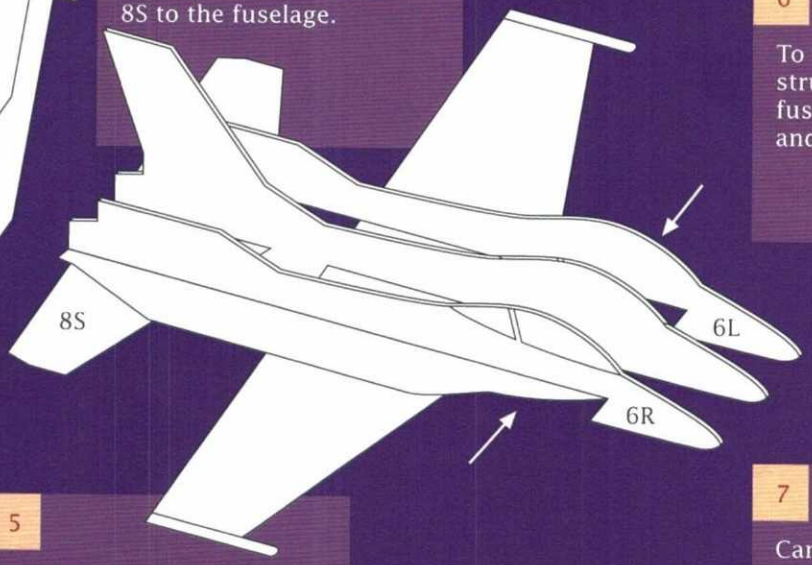
3

Glue piece 7B to the bottom of wing part 7W, aligning centers. For added strength, apply glue and bend over wingtips. Set dihedral as shown below.



4

Applying glue to tail tabs, fasten horizontal stabilizer 8S to the fuselage.



6

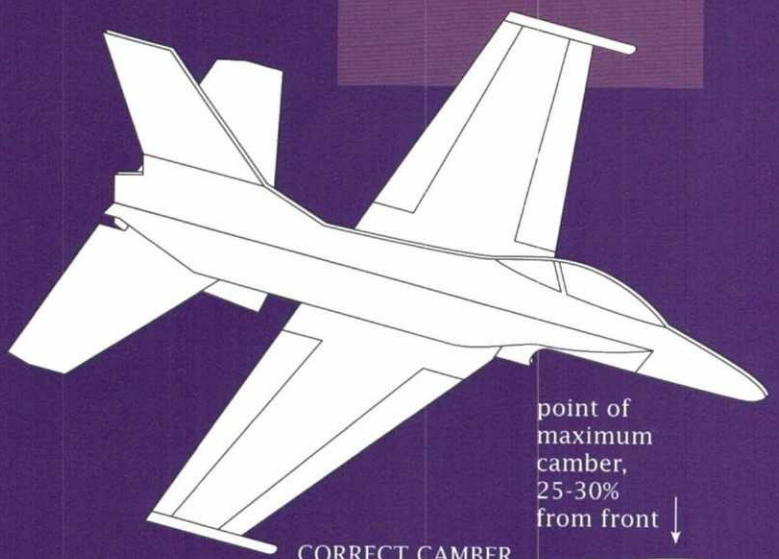
To finish the plane's structure, apply glue to fuselage pieces 6L and 6R and press into position.

5

Applying glue to the wing tabs, fasten wing assembly to the fuselage, aligning center lines.

7

Camber the wings by curving the paper gently between thumb and forefinger. See below.



WINGS 10°
HOR STAB -10°

point of maximum camber, 25-30% from front

CORRECT CAMBER

NOTE
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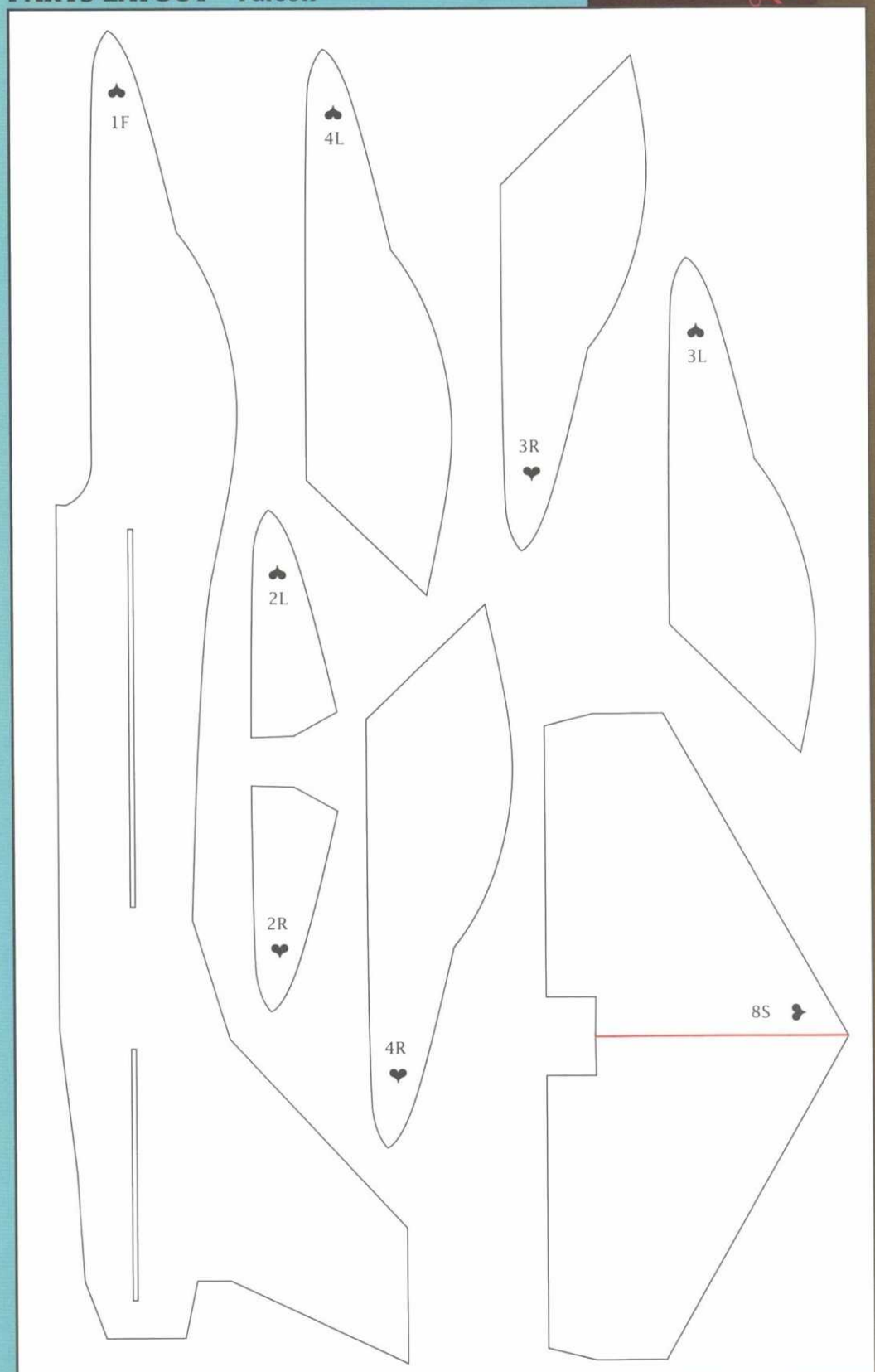
NOTE
CUT OUT PHOTOCOPY ONLY

PARTS LAYOUT – Falcon



jet development

The extensive use of electronics did not originate in the Airbus. Neither did supercruise capability orginate with the Concorde. Both had their origin in the Canadian Avro Arrow, an aircraft on which development began in 1952. **(#10, p 55.)** The plane was designed as an interceptor to defend the vast Canadian north. For this role it had to be capable of supersonic speed at high altitude for its entire flight. Supersonic research in Britain and the United States provided basic knowledge for the construction of this all-aluminum alloy aircraft. Five Arrows had been built and test flown before the program was halted for political reasons in 1958.

The Arrow's external surface was completely smooth and it carried all its stores, such as fuel, weapons, and electronic devices internally. It had steeply swept delta (triangular) wings and no horizontal stabilizer. To avoid pitch-up problems in such wings, each wing had a notch in its leading edge. The sleek plane was designed for a speed of Mach 3, a speed in excess of its thermal barrier. This meant it had to have air conditioners to keep its skin cool.

The Arrow was the first plane to be controlled electronically (*fly-by-wire*). In this system wires run to small motors that move the control surfaces instead of mechanical linkages.

Its navigation and guidance systems were also entirely electronic. The idea was to have an airplane that could fly and do battle entirely by itself, computer controlled, with only the pilot keeping an eye on things. Computer control was necessary because to maneuver at speeds in excess of Mach 2 requires quick response beyond human capability. This experimental plane was twenty years ahead of its time and influenced future developments in aircraft design.

One plane to benefit from fly-by-wire control and electronic systems research was the General Dynamics F-16 Falcon, developed in the 1970s. **(#11, p 60.)** This lightweight, high-speed, and maneuverable fighter was in some ways to fighters what the Airbus was to transports – simple and economical. Like the Arrow, it is completely electronic in its controls and systems. Unlike the Arrow, its airframe is made mainly of lightweight plastic composites instead of metal. These materials are very strong, making the airplane virtually indestructable under the conditions of high-speed maneuvers.

The Falcon introduced a new shape to jets. It has clipped delta wings with a tail and ventral fins. The wings are smoothly blended into the fuselage with *strakes*, which are long leading edge extensions. The entire fuselage- strake-wing combination produces lift. With its large "shark's mouth" air inlet beneath the cockpit, it appears

NOTE
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- Score lines in red.
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NOTE
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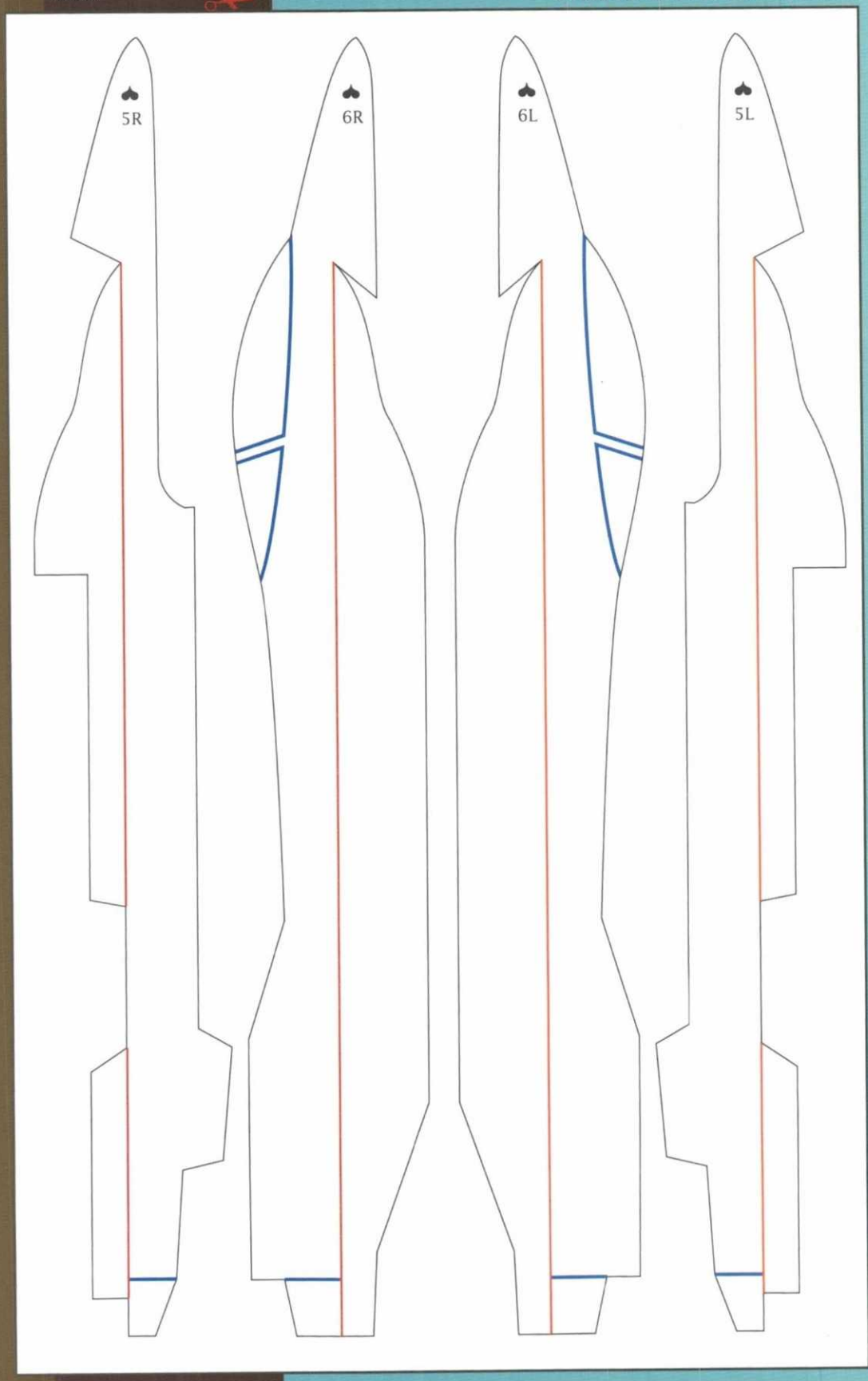
PARTS LAYOUT – Falcon



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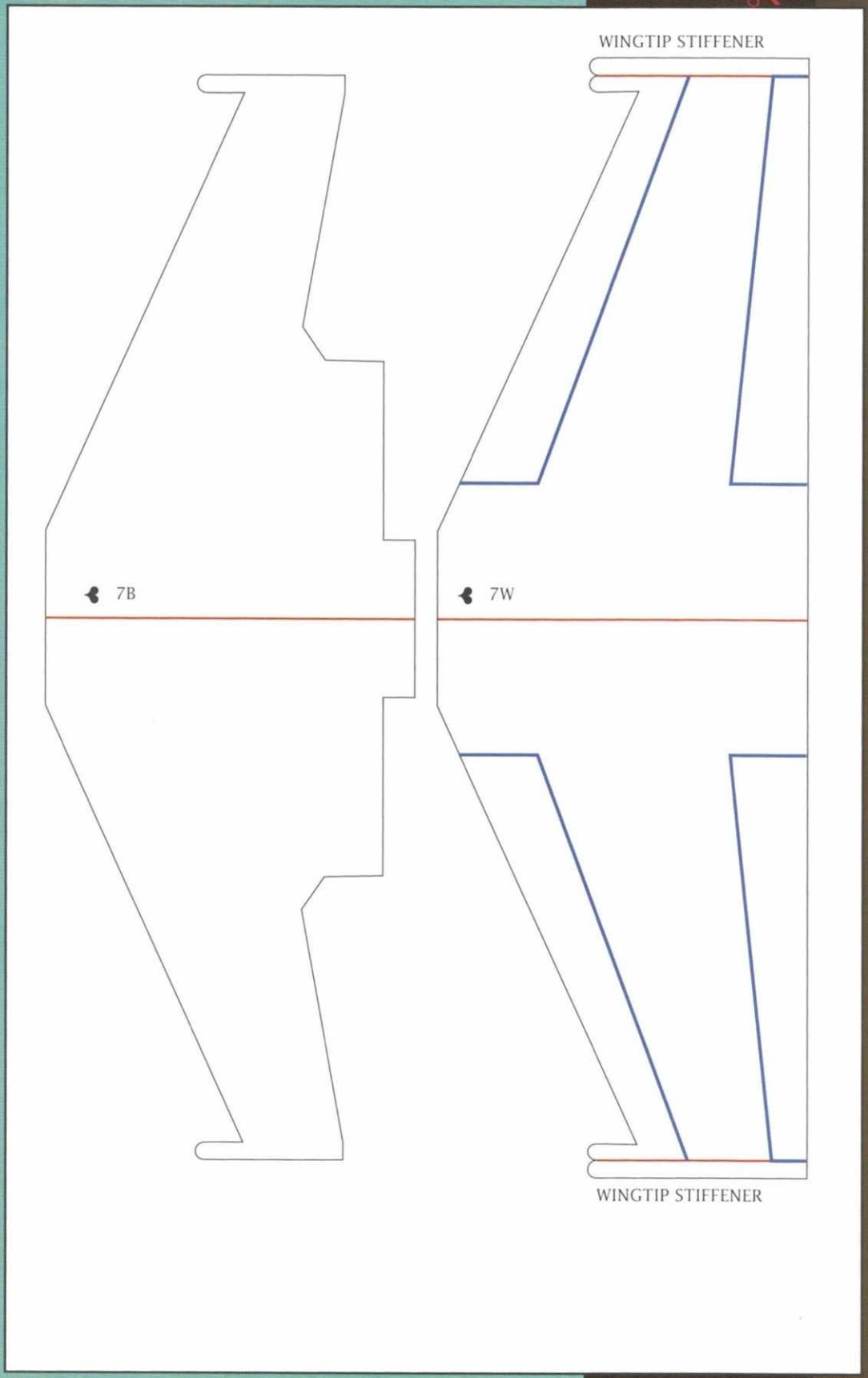
NOTE
CUT OUT PHOTOCOPY ONLY

PARTS LAYOUT – Falcon



as though the plane is perched on top of its single turbojet engine. It flies at supersonic speed for short bursts using an afterburner This agile fighter is used by the air forces of many countries.

The new integrated airframe shape is also used in other fighters. One is the Russian MiG-29 Fulcrum, which came into service in 1985. **(#12, p 65.)** It belongs to a class of heavy multi-task fighters built by various countries. All are closely matched in performance.

This plane has twin vertical stabilizers, and the air inlets for its two large turbojet engines are beneath the fuselage. It has a rugged landing gear for operation using rough airstrips. It uses extensive electronics in its various systems, but has mechanical control links. The MiG-29, built partly of plastic composites, flies in excess of Mach 2 in short bursts, using afterburners.

This plane can out-maneuver many of its competitors because its jet nozzles can be angled to direct thrust in different directions, called *thrust vectoring.* See p 81. This capability was introduced by the Hawker Harrier in the late 1960s. In that plane thrust vectoring allowed for vertical take off and hovering. Thrust vectoring will be used increasingly in the future.

Mikoyan MiG-29 Fulcrum

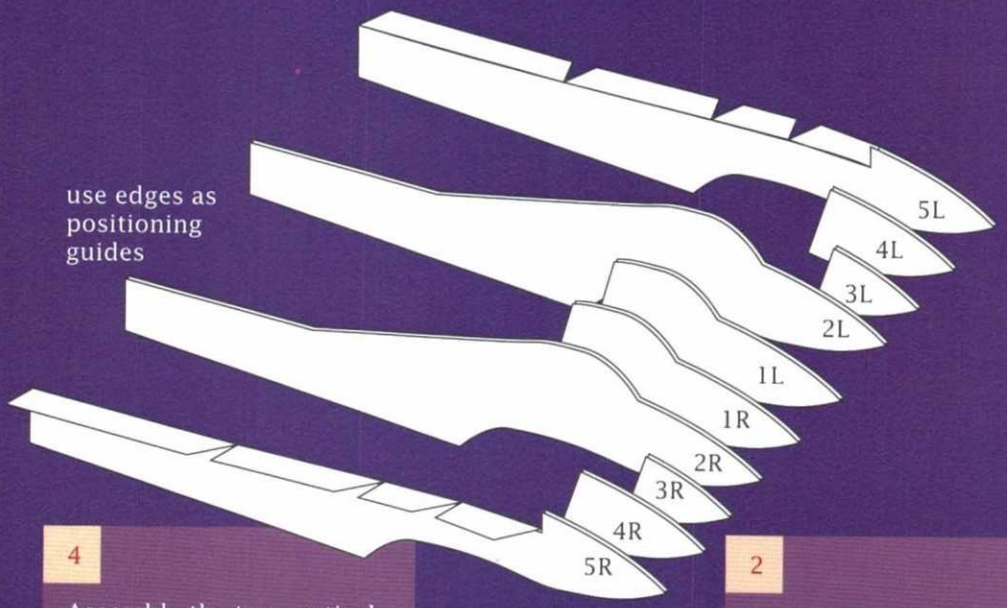
super maneuverability

12

Building the Fulcrum

1

Photocopy the parts layouts for this model. Then cut out and prepare the pieces. (See the general instructions beginning on p 4.)

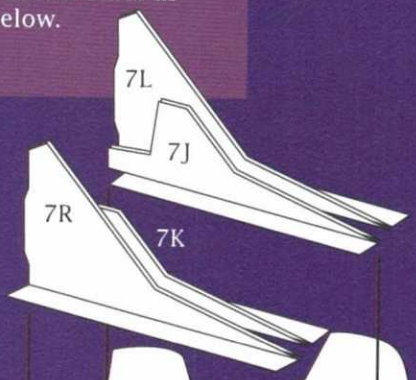


2

Glue pieces 1R and 1L through 5R and 5L to build up fuselage layers, carefully aligning parts.

3

Bring wing parts 6L and 6R together. Glue piece 6B to the bottom, aligning centers. Set dihedral as shown below.

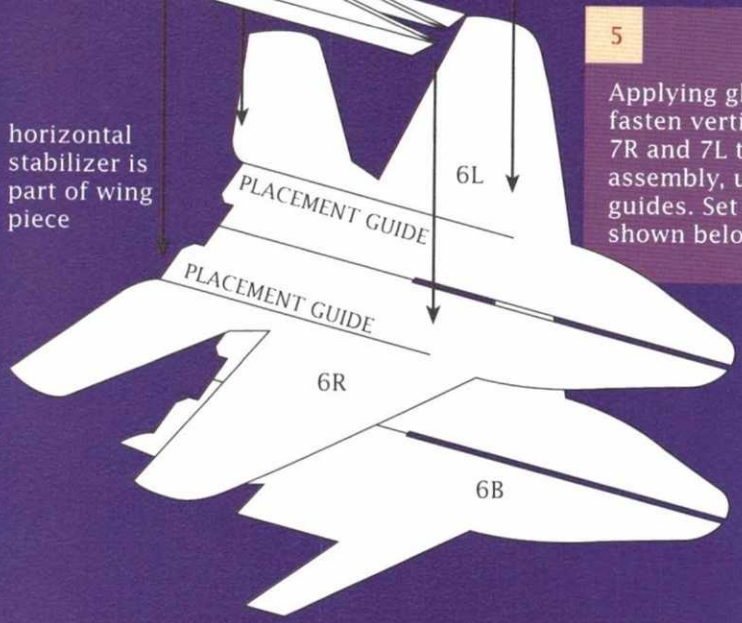


4

Assemble the two vertical stabilizers. First apply glue to 7J and attach to 7L. Then apply glue to 7K and attach to 7R.

5

Applying glue to tabs, fasten vertical stabilizers 7R and 7L to the wing assembly, using placement guides. Set dihedral as shown below.



6

Applying glue to the wing tabs, fasten wing assembly to the fuselage, aligning center lines.

7

Camber the wings by curving the paper gently between thumb and forefinger. See below.

WINGS 2°
VERT STAB 2°

CORRECT CAMBER

NOTE
- Cut on lines shown in black.
- Score lines in red.
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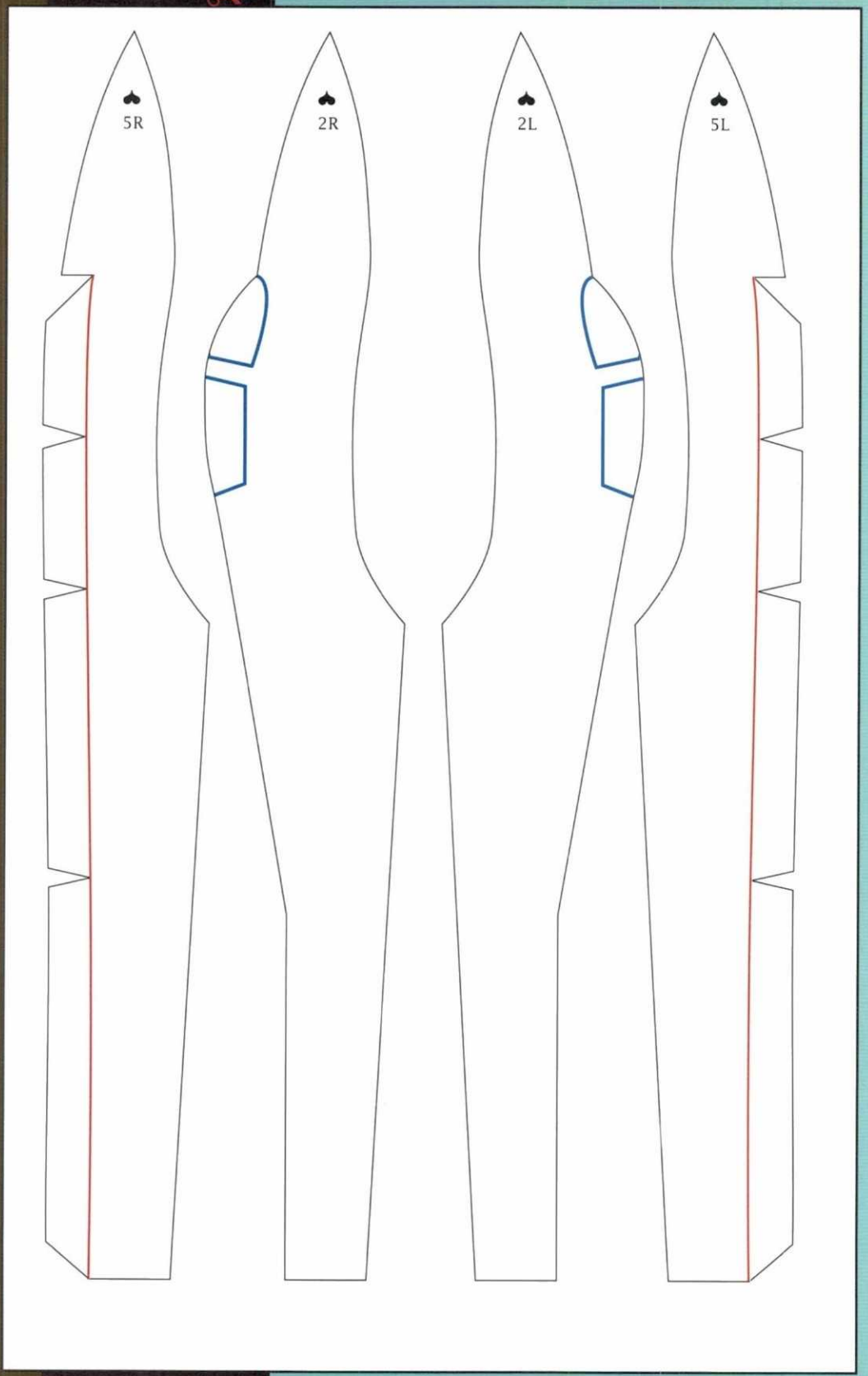
- ➤ Indicates the front edge of the piece.

NOTE
CUT OUT PHOTOCOPY ONLY

PARTS LAYOUT – Fulcrum



The military uses of aircraft pose some unique problems. One is pilot safety. There have been two solutions. One is to make planes pilotless, small, and expendable. The German Buzzbomb was an early example. Such craft can be launched from large bombers while airborne, ramjets (see p 74) giving them a range of great distances at supersonic speed. Computer controlled guidance systems make them fly accurately. They are cruise missiles.

The second solution is to make planes invisible. Ever since the invention of radar in the Second World War, planes are detected long before they are visible to the naked eye, making them easy targets. In response engineers began to design aircraft that were difficult to detect by electronic devices using what is known as *stealth* technology.

Several things make airplanes detectable by electronic devices. One is their overall shape. In order to be stealthy there can be no right-angled surfaces and no protrusions on the airplane. Because jets are already streamlined, they are ideally suited to being made stealthy. The materials used in their construction also affects an airplane's stealthiness. To be stealthy less metal must be used. Another is that most fighters have so many different stores attached beneath their wings and fuselages. To be stealthy these need to be placed inside the fuselage. Yet another is the heat streaming from their jet nozzles. To be

NOTE
- Cut on lines shown in black.
- Score lines in red.
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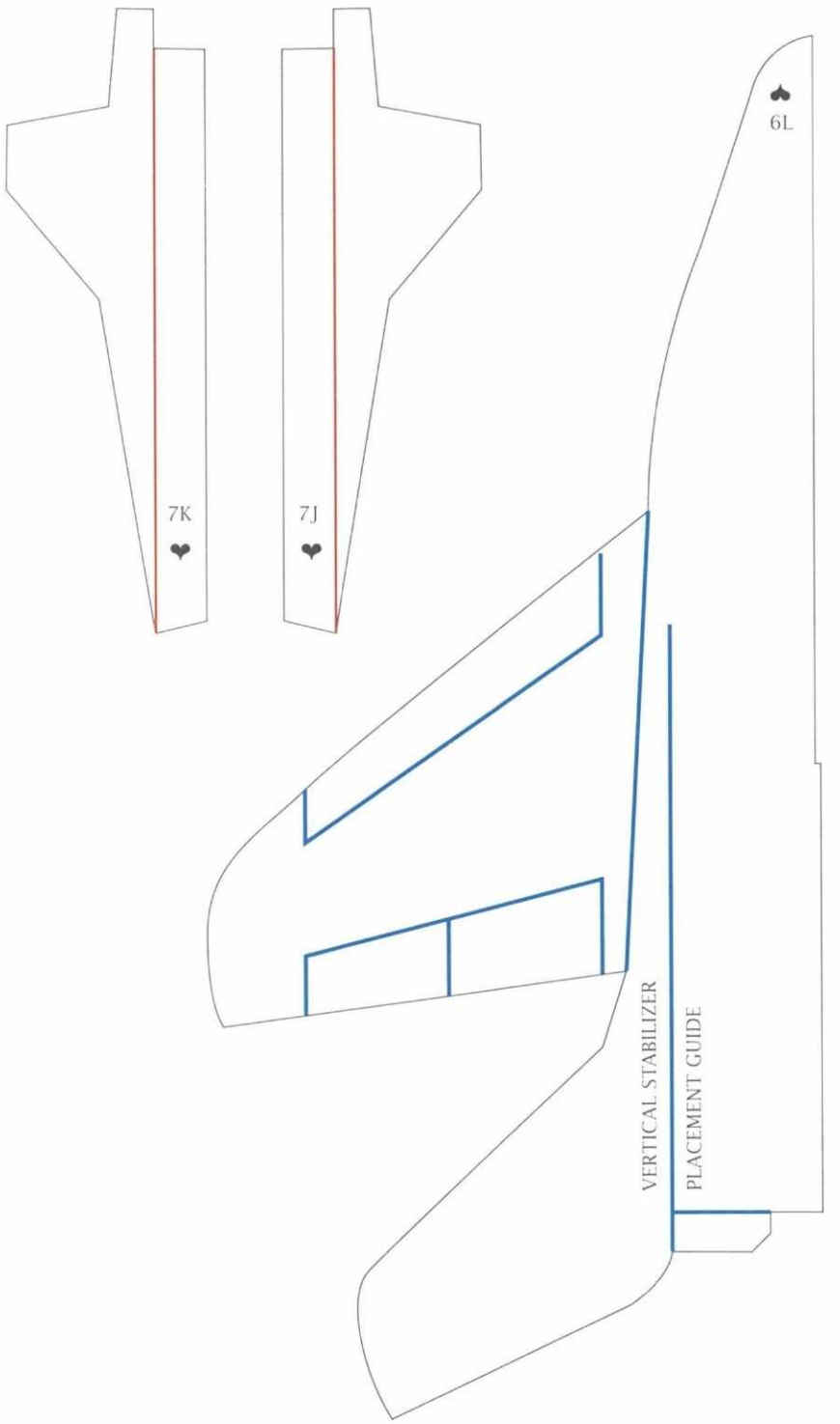
PARTS LAYOUT – Fulcrum



stealthy the nozzles need to be shielded.

One of the first stealthy airplanes, however, is anything but smooth. From the Skunkworks at Lockheed came the unique F-117 Nighthawk, designed for nighttime attack operations. **(#13, p 71.)** For this role it need not be fast or maneuverable. This subsonic plane's unusual delta shape, with multi-faceted geometric panels and black skin, make it almost invisible to both electronic devices and, at night, to the naked eye. Although built in 1977, the Nighthawk was kept a secret until it saw extensive use in the Gulf War in 1991.

All future fighters will be stealthy. The Lockheed F-22 Raptor is an example. **(#14, p 77.)** Currently in the development stage, it will come into operation sometime early in the 21st century as a maneuverable, supersonic and supercruise, multi-role fighter, that will replace many current models. It is smooth skinned with no right angles and no protrusions. It is the first fighter design since the Arrow where all stores are carried internally. The Raptor's thrust vectoring jet nozzles are buried and shielded.

private jets

With the increase in size and complexity of businesses, and the placement of outlying facilities in remote locations not serviced by regular jet flights, there was a need for fast transportation for a few people to these areas on a frequent basis. Airplanes, owned and operated by the corporations themselves, were the answer. Many airplane manufacturers build jets to meet this need. The first, the Gates Learjet, in 1963, has been built in large numbers. **(#15, p 83.)** This six-passenger aircraft flies at a speed of about 500 miles per hour and is powered by two turbojet engines. Because of its speed and suitable size, the Learjet also serves as air ambulance in some countries.

Even smaller and simpler jet propelled planes are being built as smaller and smaller turbojet engines are being developed. Some are made as sport planes for private use, others as small business jets. One currently being test flown is the four-seat British CMC Leopard. **(#16, p 89.)** It is the size of the average family car. This 400-mile-per-hour plane is powered by two small turbojet engines.

Increasingly, propellers are being attached to turbojet engines to make turboprops. See p 80. This idea is not new. The Vickers Viscount was the first to do so in 1948. Today, a variety of airplanes are turbo-

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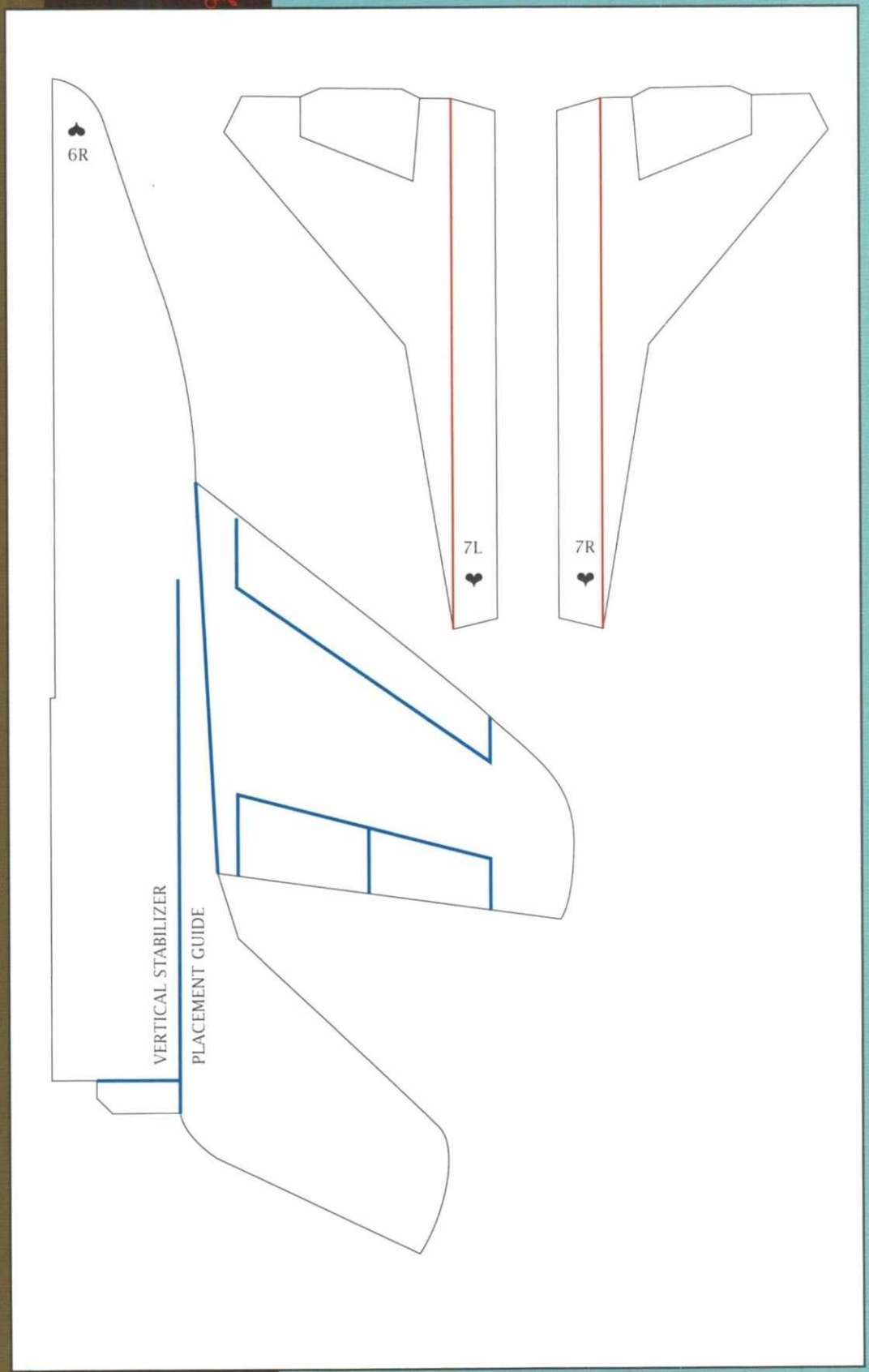
PARTS LAYOUT – Fulcrum



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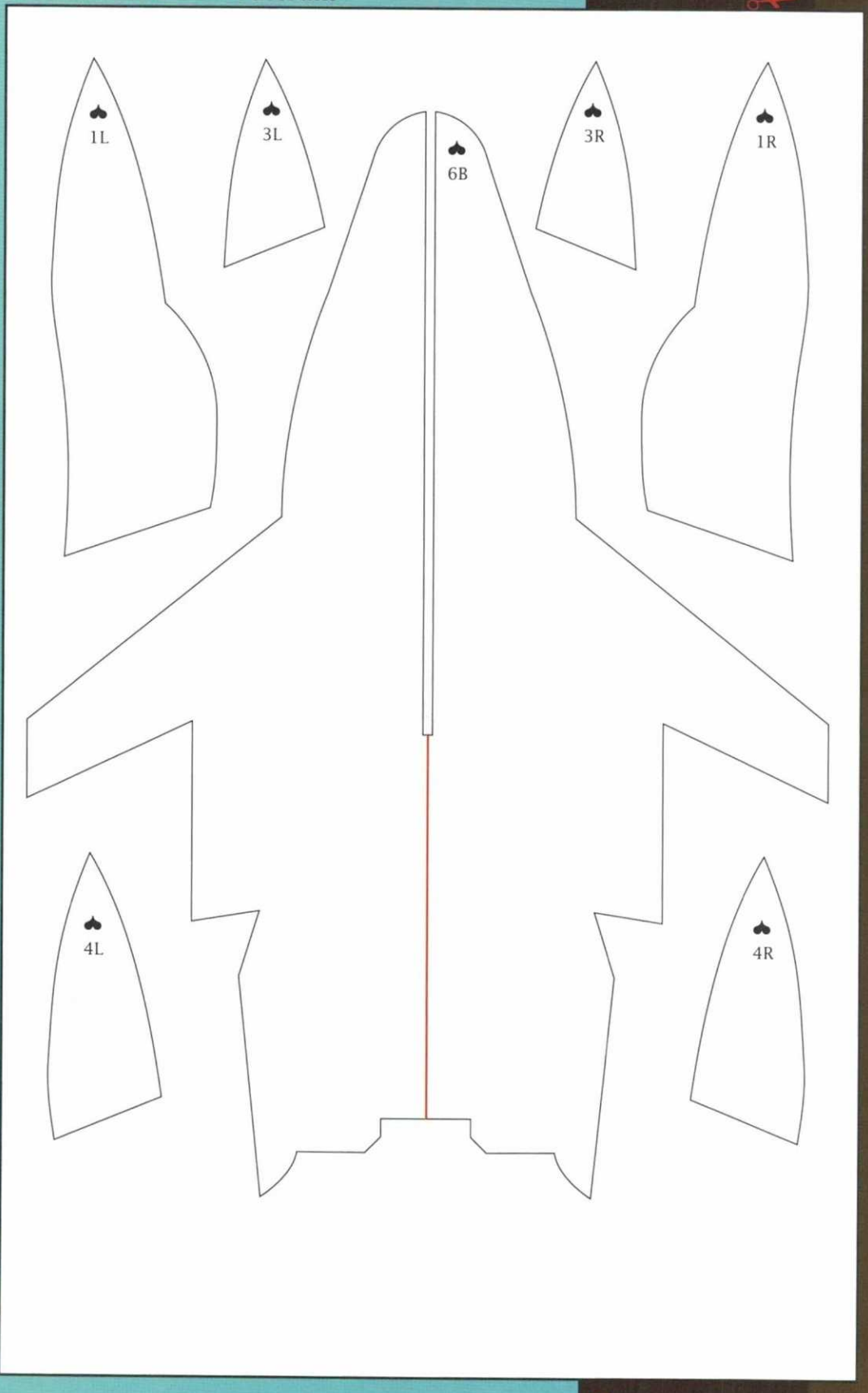


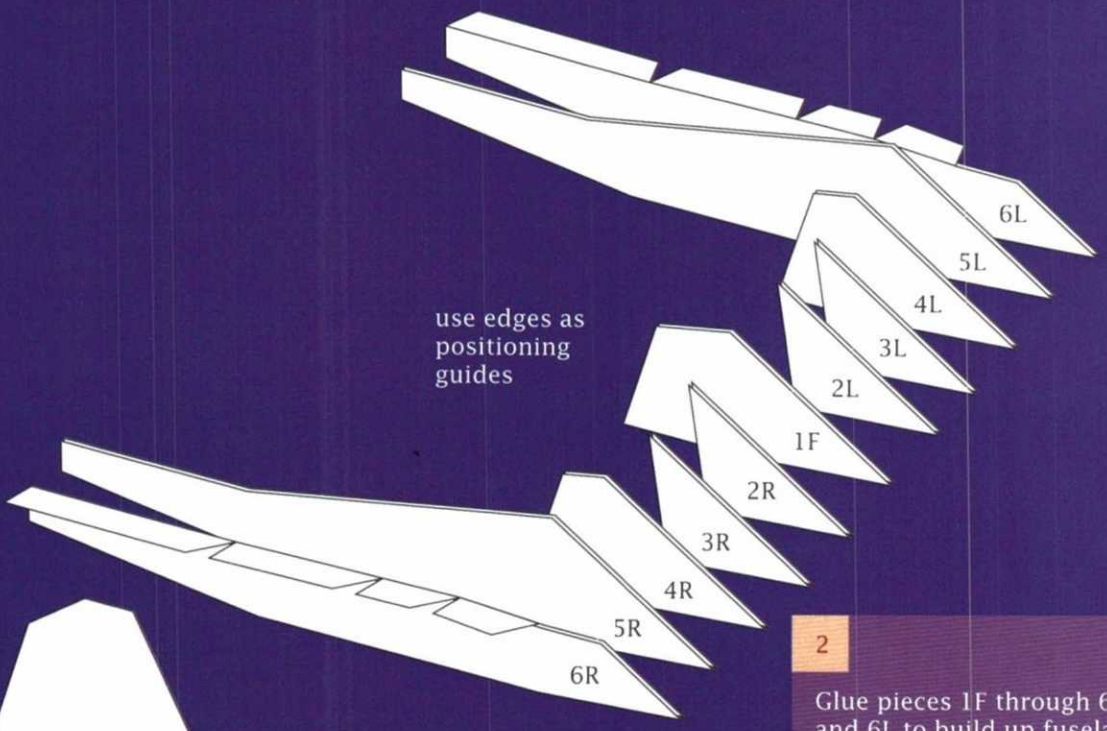
prop powered, from crop dusters to airliners. Because these propulsion systems are fuel efficient and extraordinarily quiet, there is increasing use of them for commuter planes on short-trip passenger flights over populated areas.

The future of jet propulsion is bright. It will continue to develop with lighter, more powerful, more fuel-efficient, and quieter propulsion systems in airframes designed for a wide variety of tasks.

Building the Nighthawk

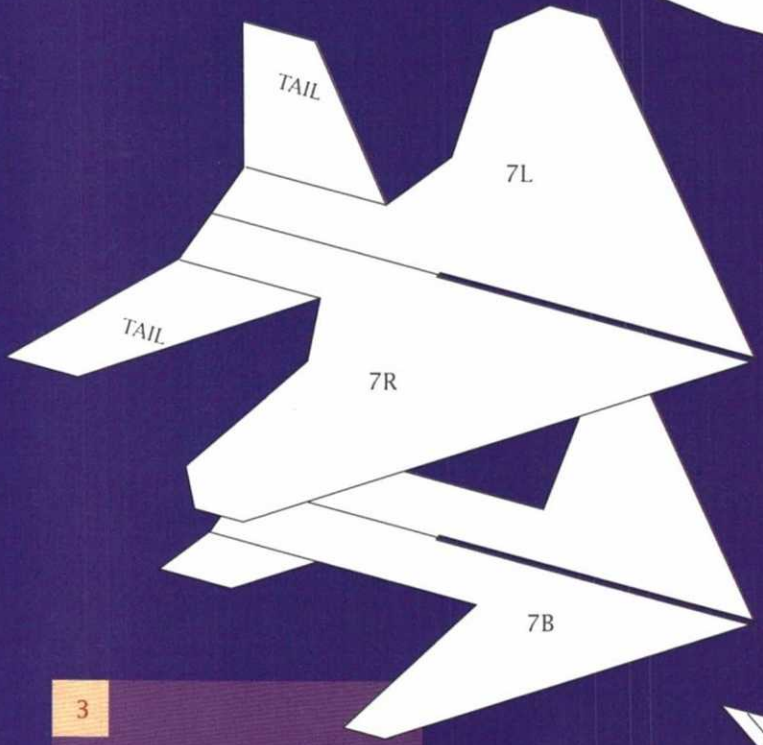
1

Photocopy the parts layouts for this model. Then cut out and prepare the pieces. (See the general instructions beginning on p 4.)



2

Glue pieces 1F through 6R and 6L to build up fuselage layers, carefully aligning parts.

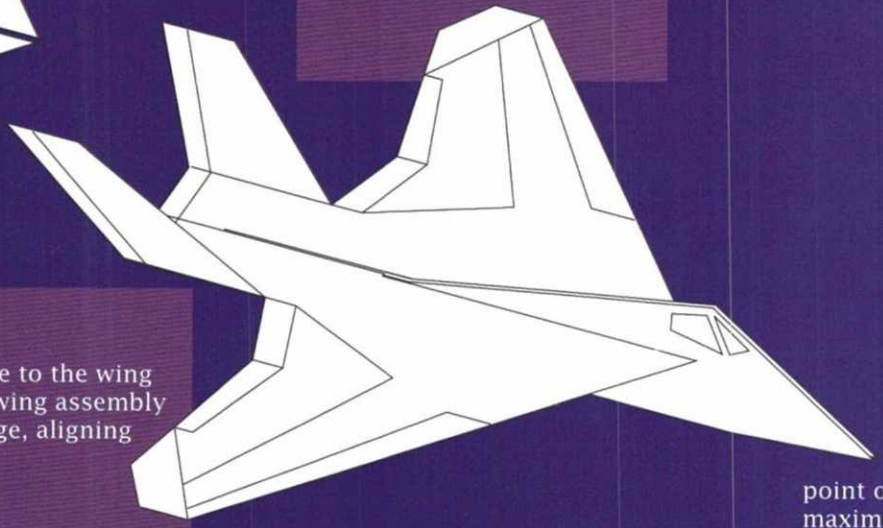


3

Bring wing parts 7L and 7R together. Glue piece 7B to the bottom, aligning centers. The V-tail is part of wing piece. Set dihedral of both as shown below.

7

Camber the wings by curving the paper gently between thumb and forefinger. See below.



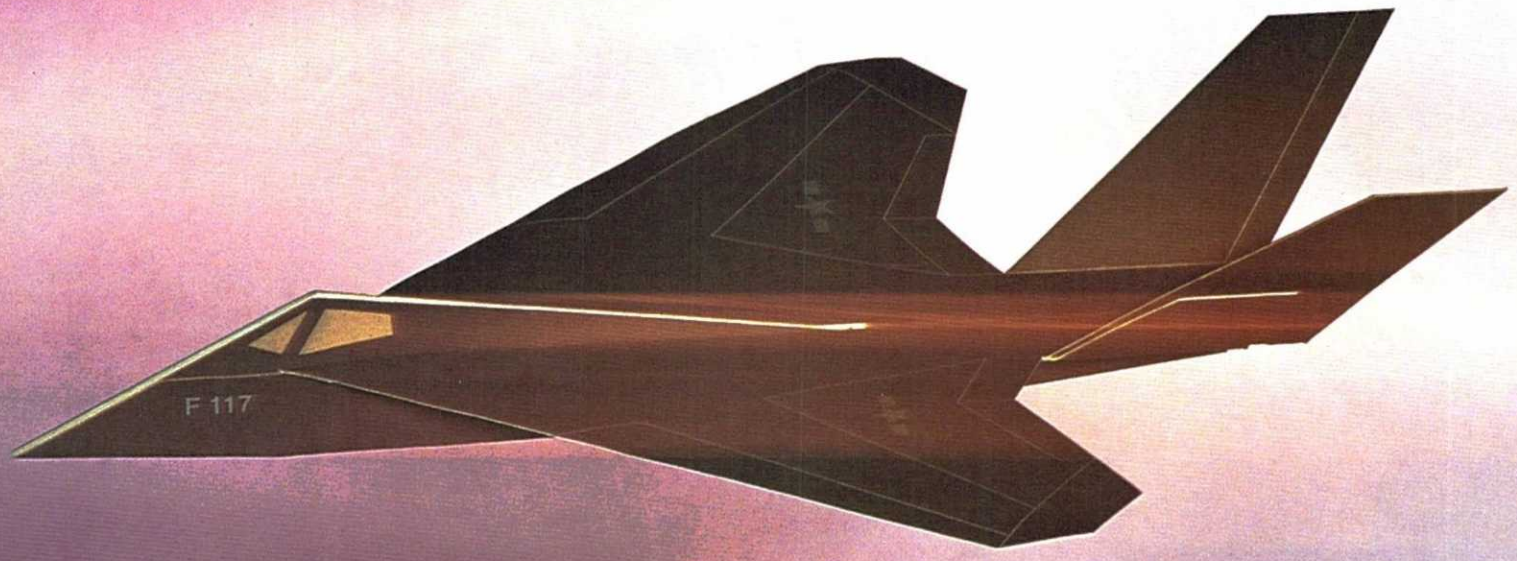
6

Applying glue to the wing tabs, fasten wing assembly to the fuselage, aligning center lines.

WINGS 5°
V-TAIL 65°

Lockheed F-117 Nighthawk

stealth

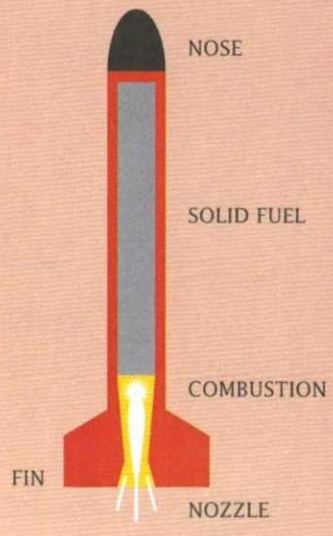


13

jet propulsion systems

1 THE SIMPLEST JET

The simplest of all jets is the solid-fuel rocket. It has no moving parts and there is no way to control how fast the fuel burns in such an engine or to turn it off once lit. It is either off or on. All the propelling charge is stored right in the engine's combustion chamber, burning from one end to the other until it is all consumed. It burns without air, the oxydizer is contained within the fuel. At the rear end is a nozzle through which the jet of hot combustion gas escapes. The action of the burning gas escaping in one direction causes an equal reaction, propelling the rocket in the opposite direction. Fins help to guide the rocket, pointing it in the direction of flight. This was the Chinese "arrow of flying fire" and is the forerunner of all other modern jets.



NOTE
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NOTE
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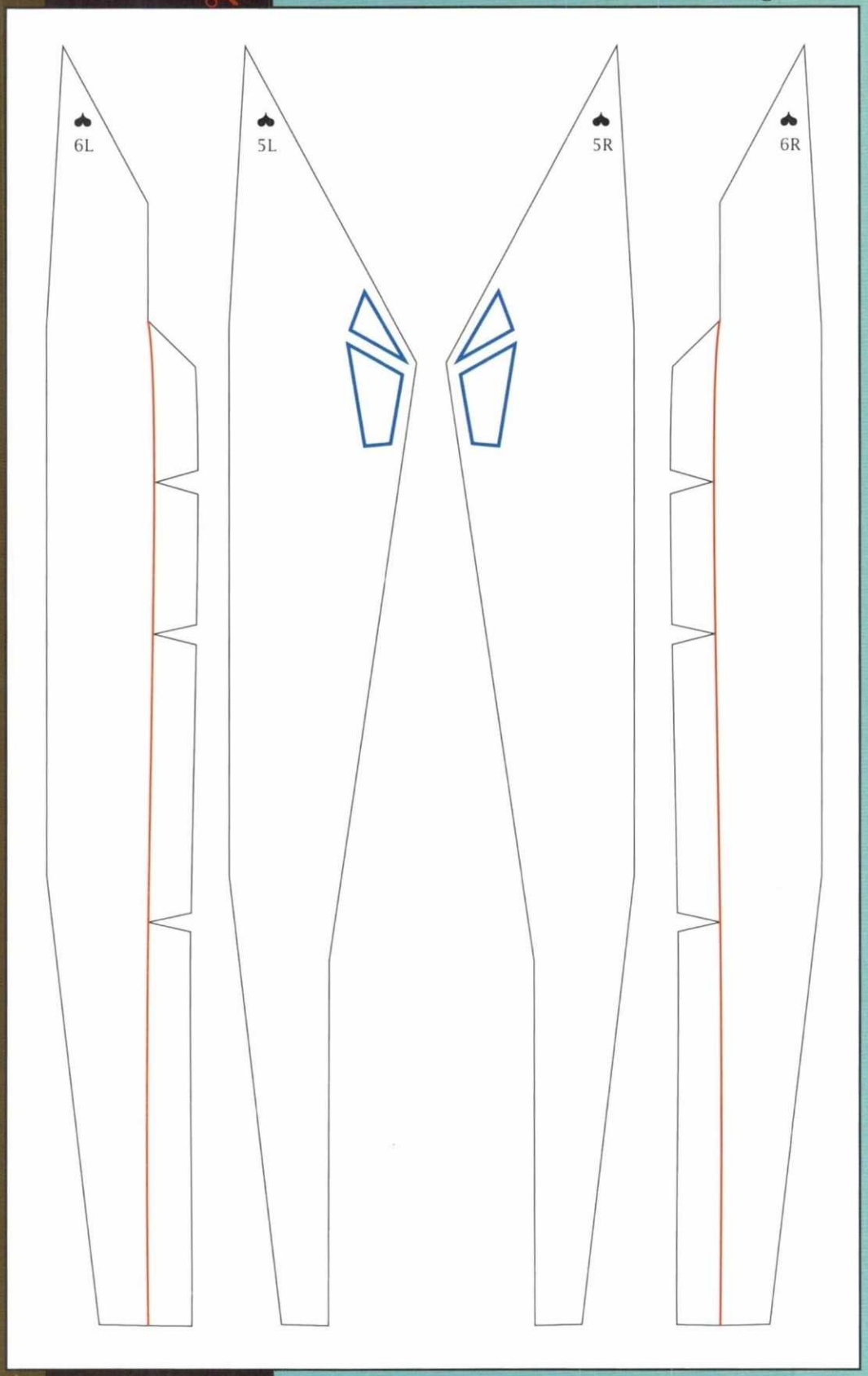
PARTS LAYOUT – Nighthawk



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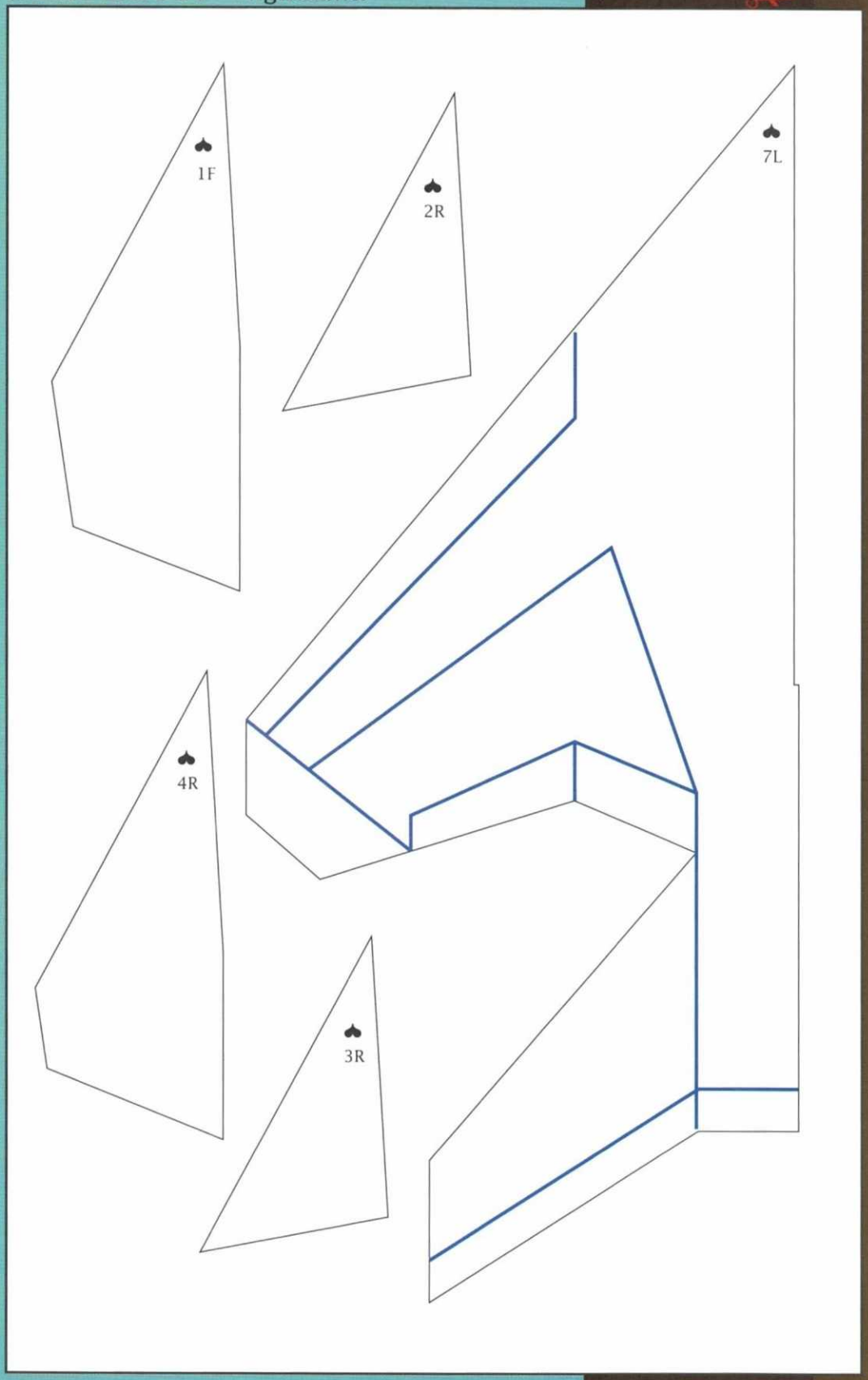
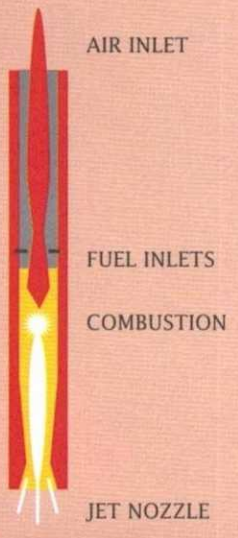


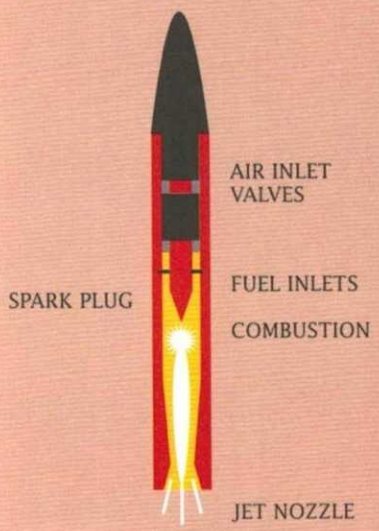
2 RAMJET

As do solid fuel rockets, ramjets have no moving parts. Before a ramjet can operate it must first be set in motion by some other means. A solid fuel rocket is often used. Once the ramjet moves through the air at high speed, air is rammed into the air inlet at the front of the engine. As air enters the engine, it cannot move through the engine fast enough to make room for the new air coming in. The ramming action squeezes the air, compressing it. This makes the air very hot. This hot air then moves back past the fuel inlets, vaporizing the stream of liquid fuel and igniting it. The mixture of fuel and air burns continuously in the combustion chamber. The pressure generated by the combustion sends a flaming exhaust out the jet nozzle. Reaction to this force drives the jet forward. Ramjets operate best at high steady speeds.



3 PULSEJET

The pulsejet consists of a tube containing air inlet valves, a combustion chamber having fuel inlets and a spark plug, and an exhaust nozzle. The engine is started by first spraying liquid fuel into the combustion chamber through the fuel inlets while pumping air into the air inlet valves. A spark plug ignites the first charge of fuel/air mixture. The pressure in the combustion chamber rises from the burning and the air valves are forced shut. The hot gases can then escape only out the exhaust nozzle. When all the gas has escaped the pressure drops, opening the air valves. By this time the engine is in motion and fresh air rushes into the vacated combustion chamber. As more fuel is sprayed the still-hot combustion chamber vaporizes the fuel and ignites the fuel/air mixture, repeating the cycle. The combustion cycle repeats over and over many times each second, making pulsejets rather inefficient (and loud).



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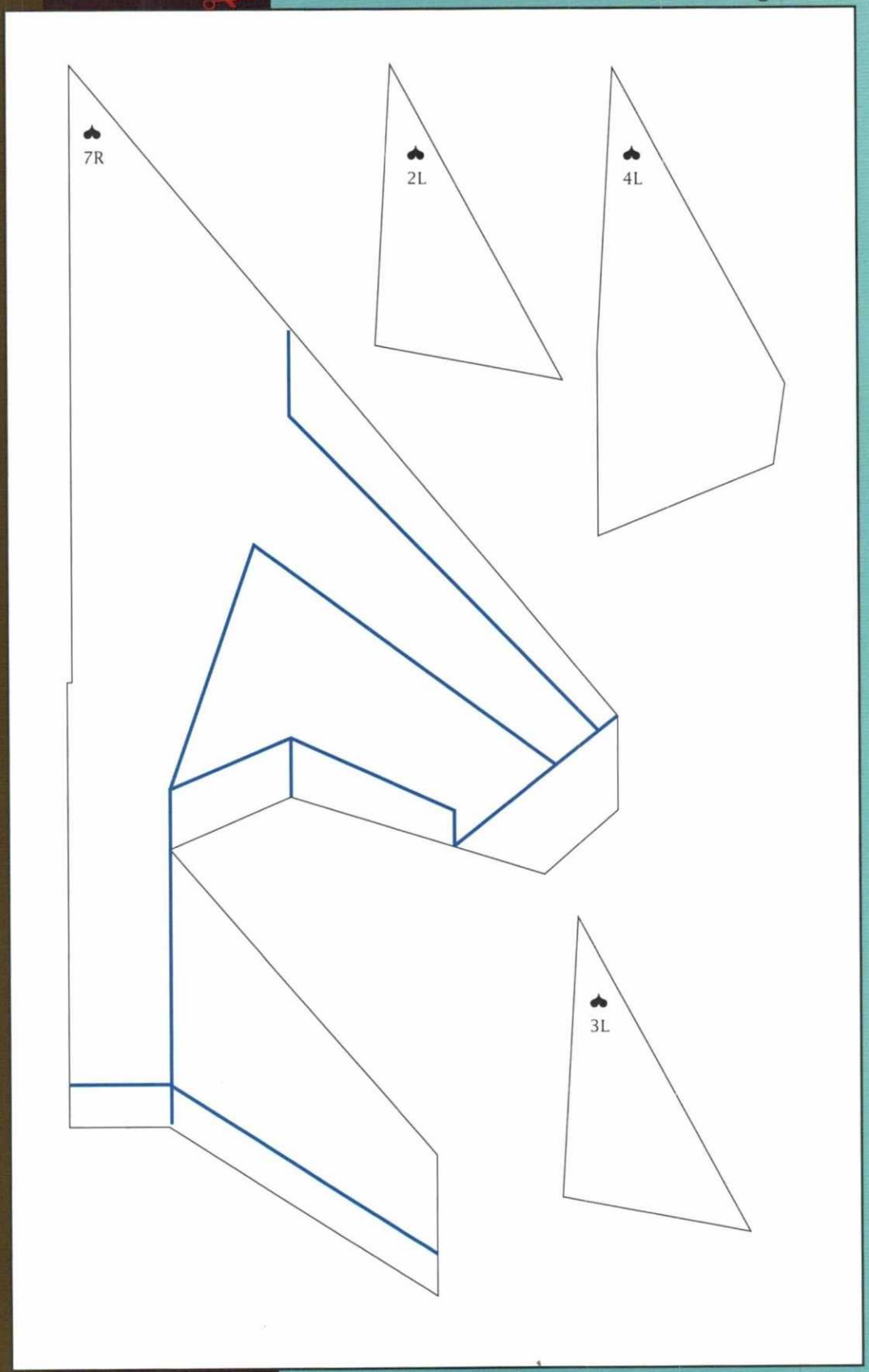
PARTS LAYOUT – Nighthawk



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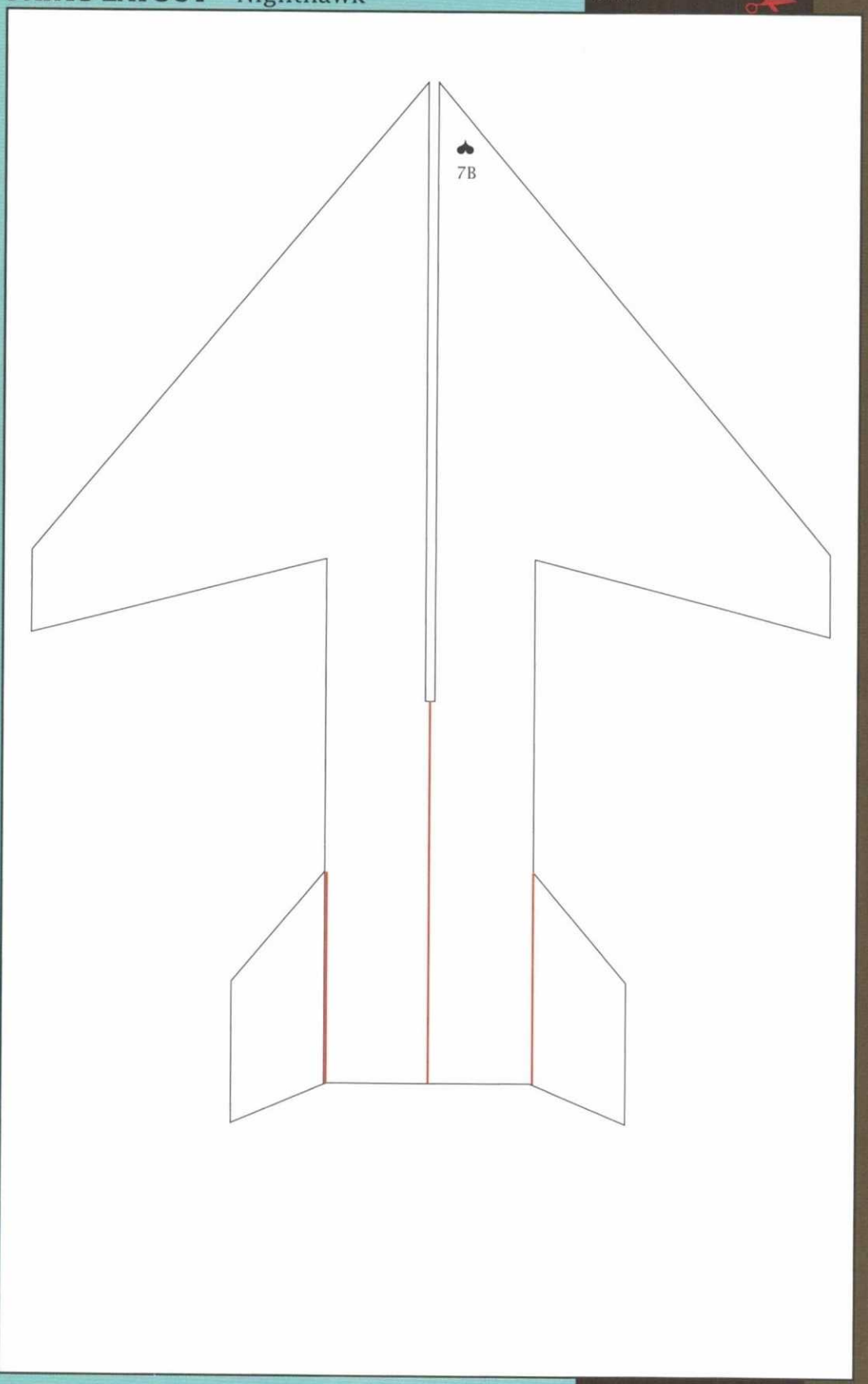
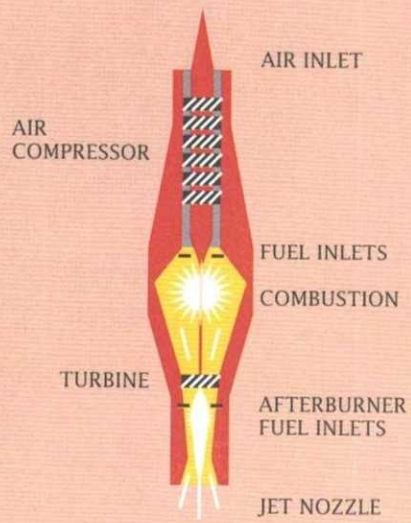
PARTS LAYOUT – Nighthawk



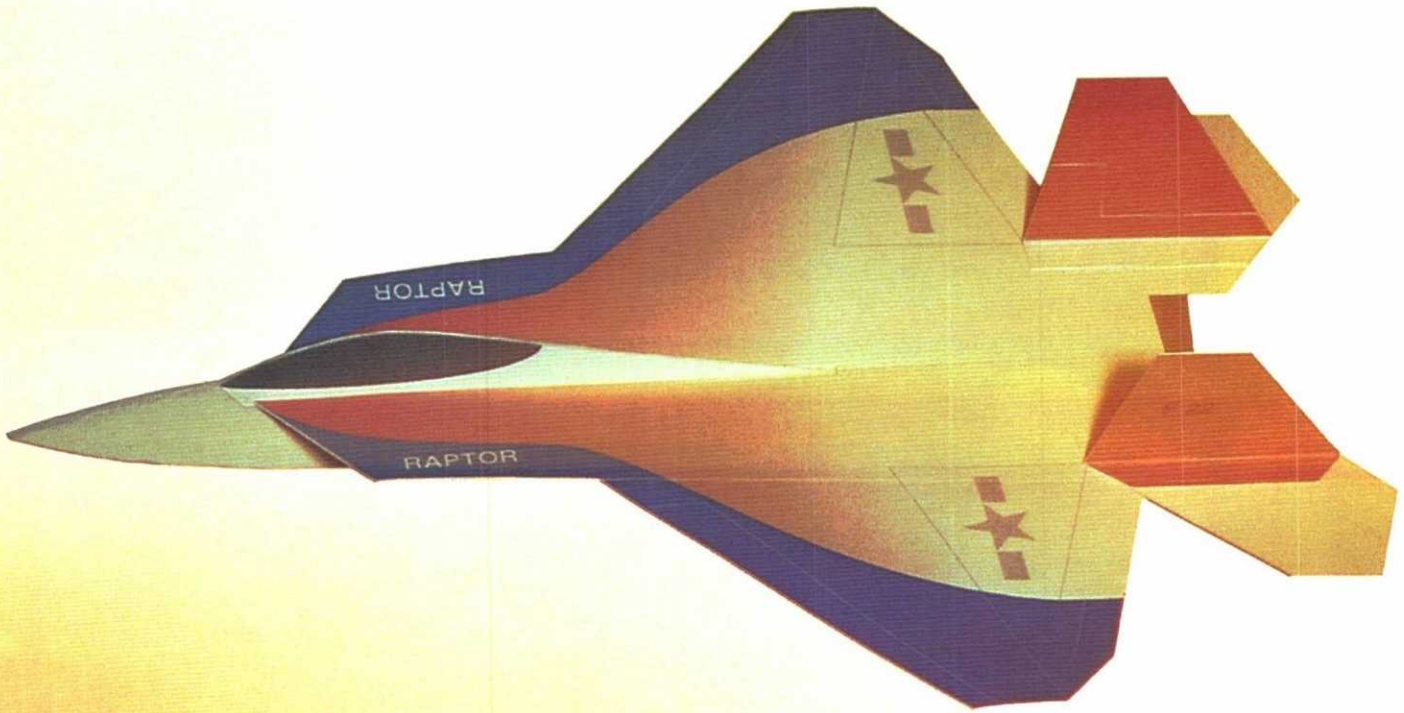
4 TURBOJET

This jet engine has an air compressor that consists of a series of discs with fanlike blades around their circumferences. As the discs spin, air is forced by the blades from one set of blades to the next. By the time air has passed through all the blades its pressure has been greatly increased, and in the process has become very hot. This hot compressed air rushes into the combustion chamber where it is mixed with fuel, which vaporizes and ignites from the heat. The heat of combustion greatly expands the volume of the air, which escapes through another disc with blades, called a turbine, located at the back of the combustion chamber. This sets the turbine spinning. The turbine is connected by a shaft to the compressor and keeps it spinning, forcing a steady stream of high pressure hot air into the engine. An afterburner gives a turbojet extra power by spraying additional fuel into the jet nozzle behind the turbine.



Lockheed F-22 Raptor

into the 21st century

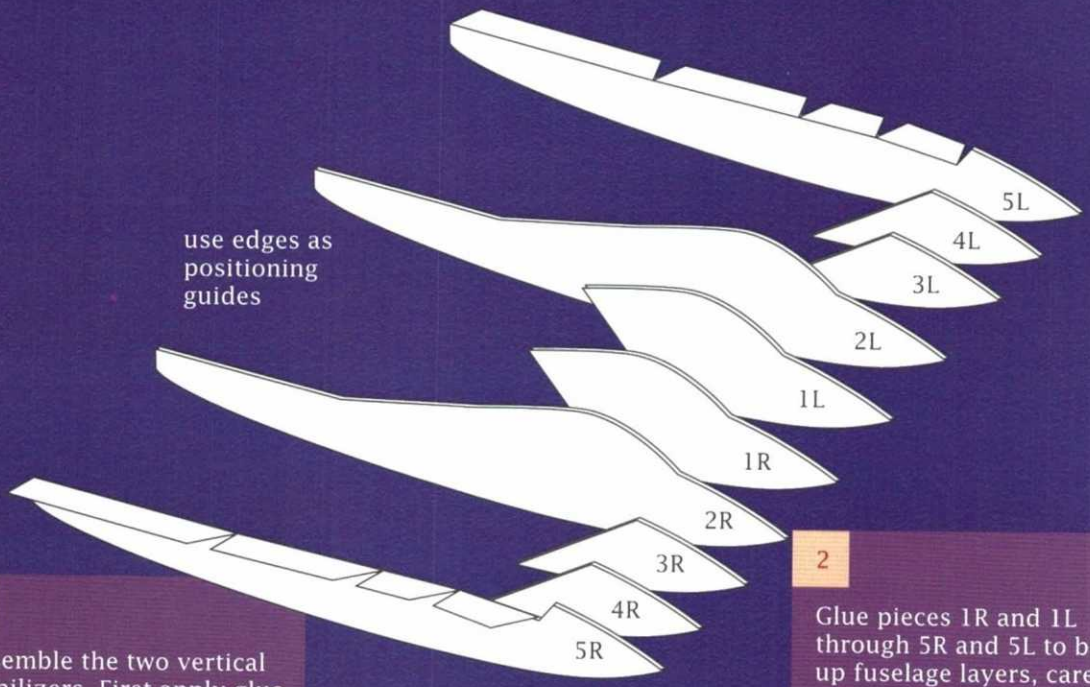


14

Building the Raptor

1

Photocopy the parts layouts for this model. Then cut out and prepare the pieces. (See the general instructions beginning on p 4.)



2

Glue pieces 1R and 1L through 5R and 5L to build up fuselage layers, carefully aligning parts.

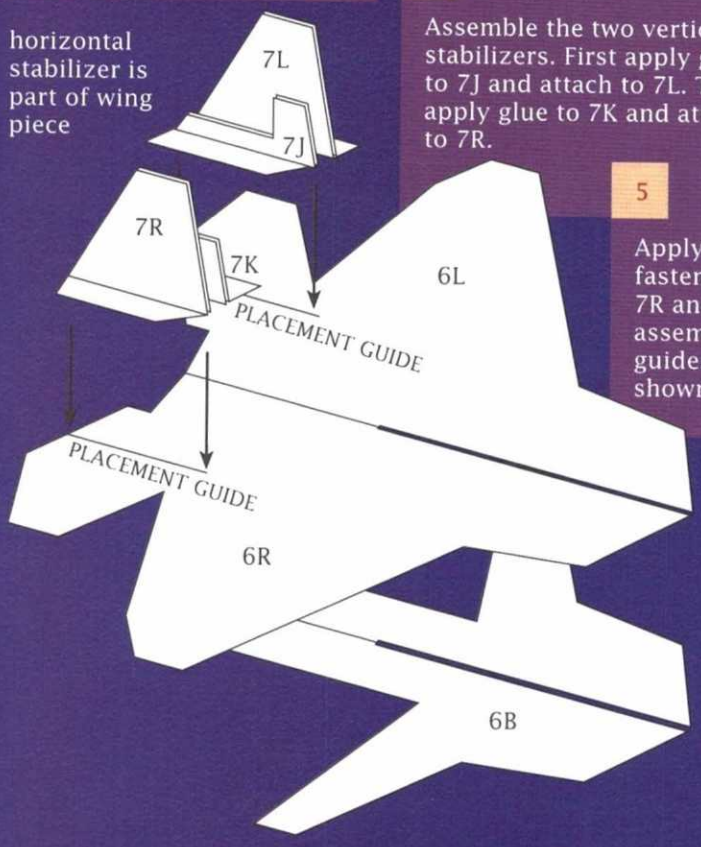
3

Bring wing parts 6L and 6R together. Glue piece 6B to the bottom, aligning centers. Set dihedral as shown below.

4

Assemble the two vertical stabilizers. First apply glue to 7J and attach to 7L. Then apply glue to 7K and attach to 7R.

horizontal stabilizer is part of wing piece



5

Applying glue to tabs, fasten vertical stabilizers 7R and 7L to the wing assembly, using placement guides. Set dihedral as shown below.

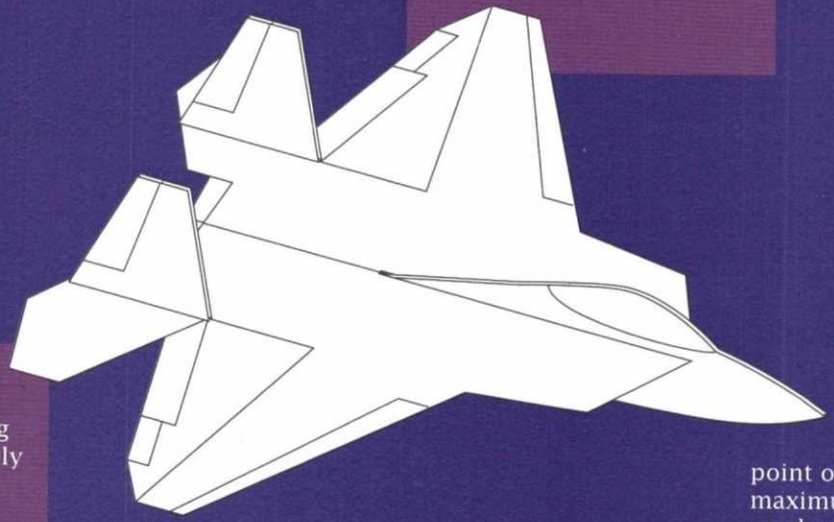
6

Applying glue to the wing tabs, fasten wing assembly to the fuselage, aligning center lines.

WINGS 2
VERT STAB 2

7

Camber the wings by curving the paper gently between thumb and forefinger. See below.

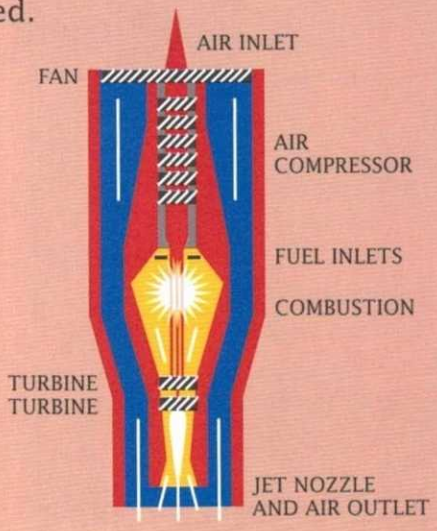


point of maximum camber, 10-20% from front

CORRECT CAMBER

5 FANJET

The propelling power of this engine comes from two sources. The inside core is similar to a turbojet. It has a compressor, combustion chamber with fuel inlets, turbine, and jet nozzle, and is the first source of power. It is different in that it has a second turbine which is connected by a shaft to a large fan ahead of the air compressor. This fan pushes air back into the engine, but only a portion of it enters the compressor. The rest passes around the turbojet core. The fan operates the same as an ordinary propeller, increasing pressure behind it without generating heat, and is the second source of propelling power. These jets have afterburners only when used in fighters. At slow speed fanjets suck much greater amounts of air into the engine. Airplanes using fanjets accelerate and climb faster. Fanjets consume less fuel and are altogether more efficient than turbojets. They are also much quieter, except when afterburners are used.



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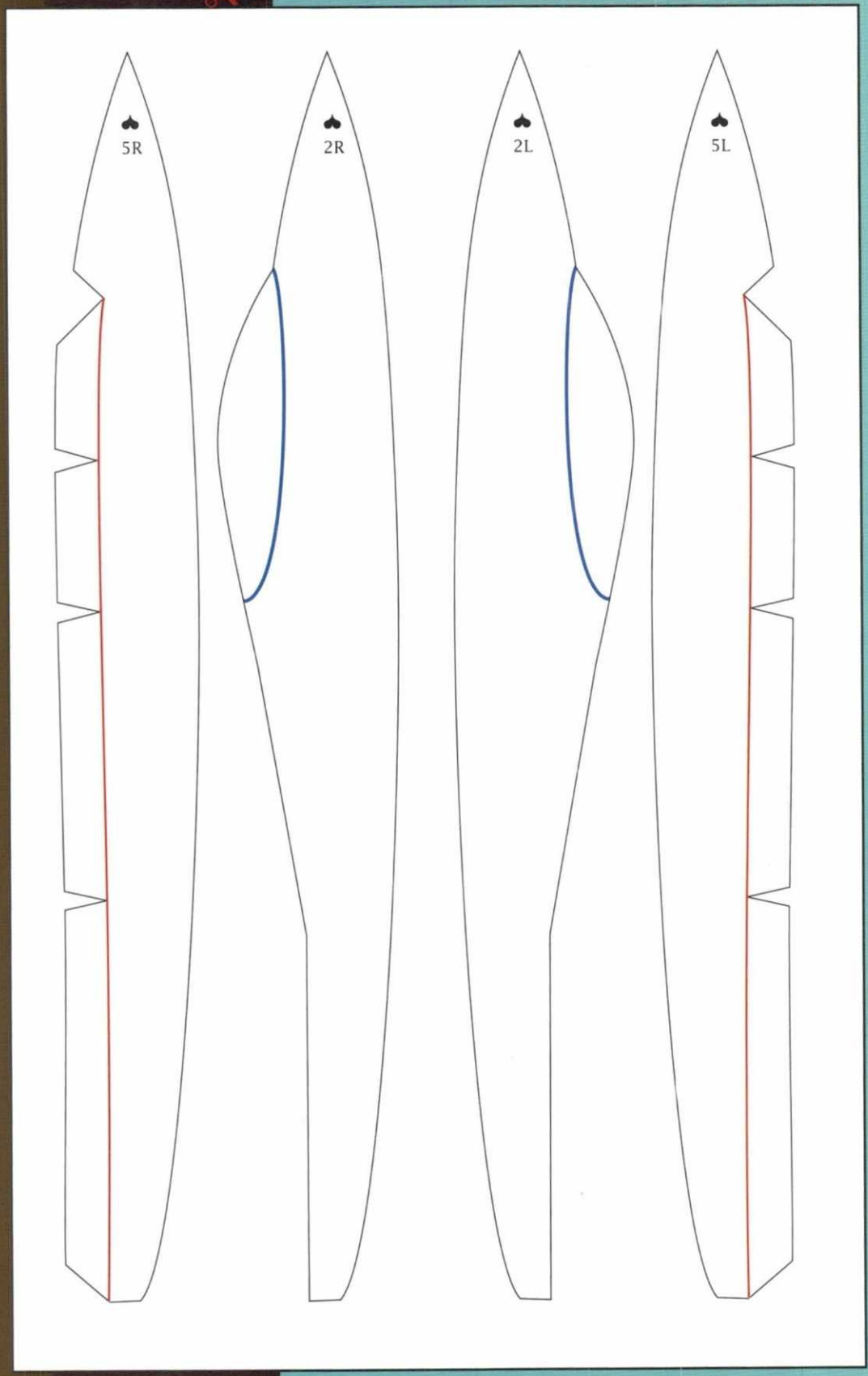
PARTS LAYOUT – Raptor



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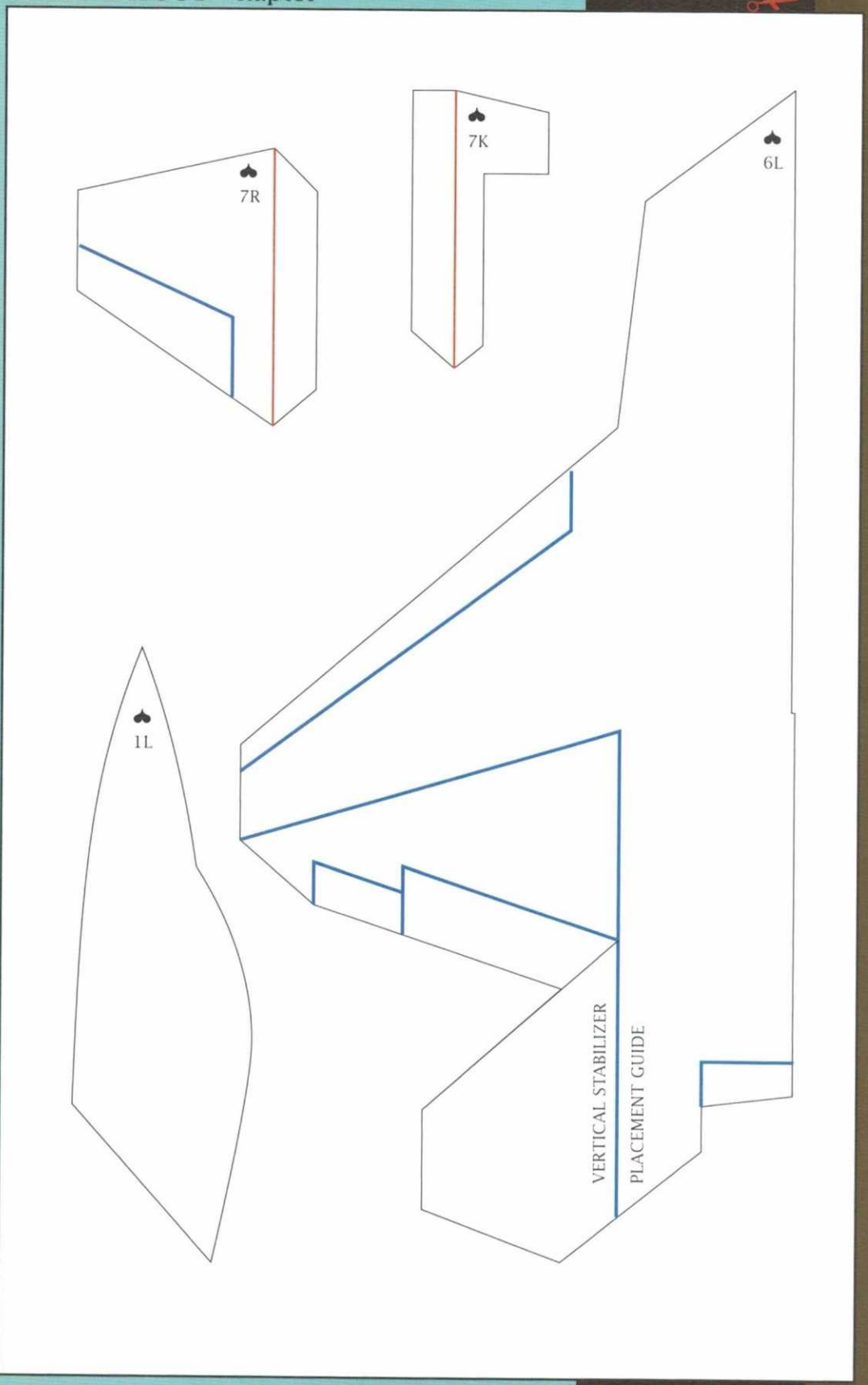
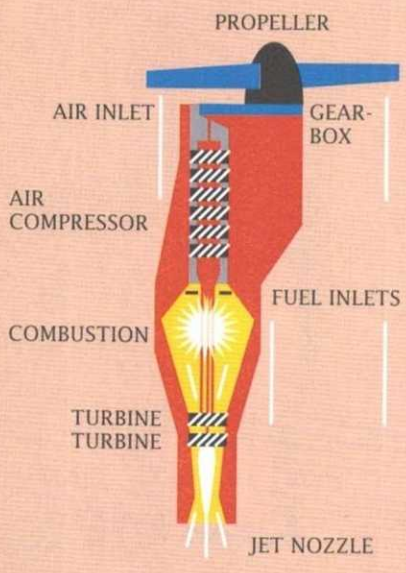


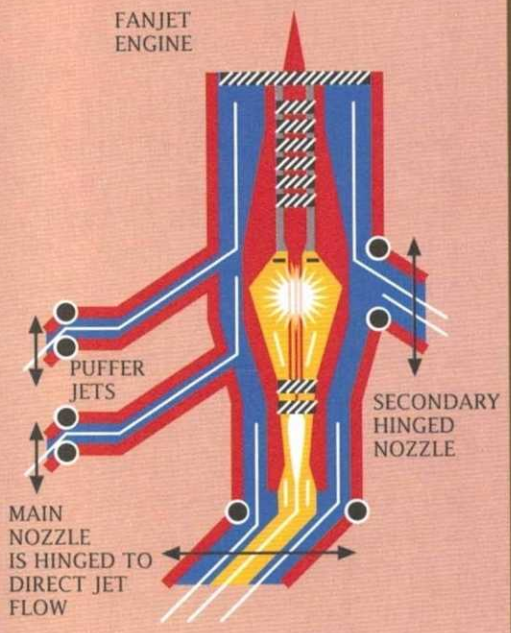
6 TURBOPROP

The turboprop consists of a turbojet engine and a regular propeller. As with the fanjet, propelling power comes from two sources, the jet and the propeller, but more power is obtained from the propeller than the jet. As does the fan-jet, the turbo-prop has two turbines, one connected to the propeller by a driveshaft and gearbox, the other driving the compressor. The turboprop is most efficient at relatively low speeds, slower than other jets. It is also much quieter than either a piston-driven propeller engine or any other jet.



7 THRUST VECTORED JET

In most jet engines the internal parts are aligned so that air moves through the engine in a straight line. The jet nozzle is fixed and the thrust is straight out the back. In the future more jet engines will have nozzles made to swivel on hinges, directing the thrust in different directions no longer in line with the engine. This is called vectored thrust. Sideways, upward, and downward thrust in an airplane increases its maneuverability. Additionally, secondary hinged nozzles give added maneuverability. They can be of different sizes and be located remotely, connected by ducts to the engine. Small nozzles are called puffer jets. They are esssential for hovering flight.



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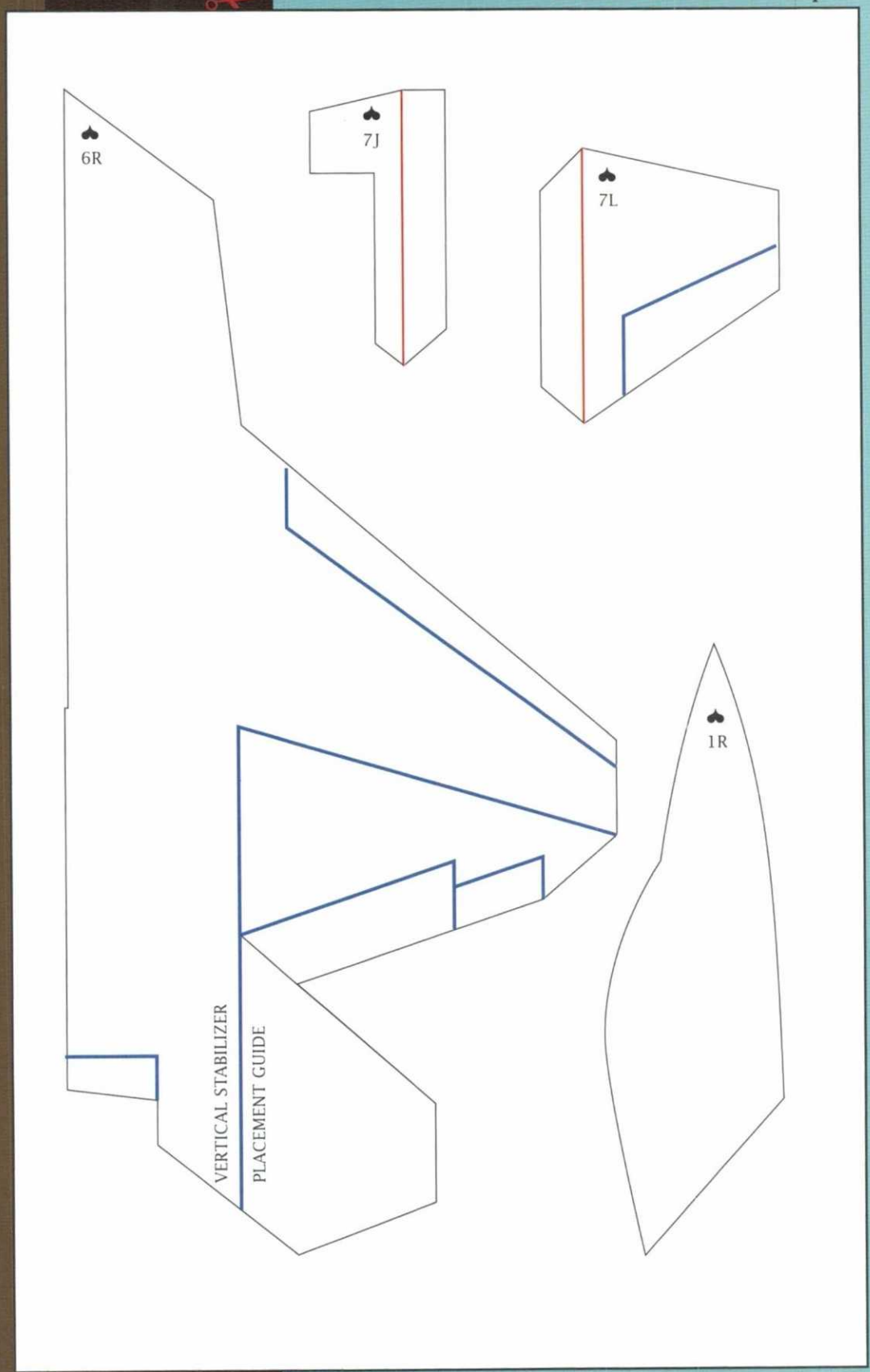

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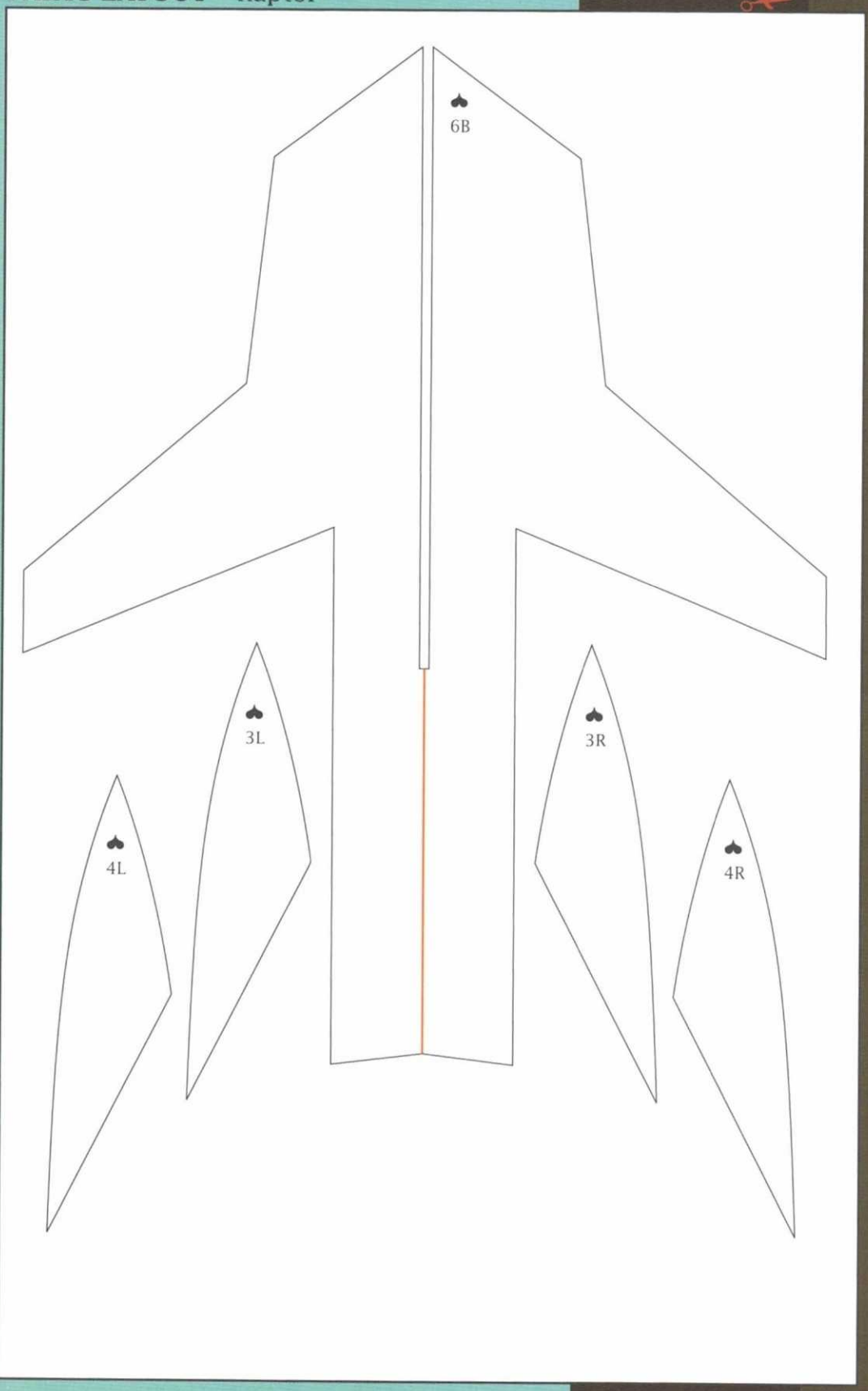
PARTS LAYOUT – Raptor



flying the paper planes

The paper jets are gliders. A paper glider's loss of height as gravity pulls it downward and forward is called sink. Every paper glider has a particular *rate of sink*. The amount of sink in relation to a glider's forward movement, is known as the *glide ratio*. At a constant airspeed the ratio of the lifting force of the wings and the resistant force of drag is exactly equal to the glide ratio. Therefore for a paper glider to have a high glide ratio, drag must be kept at a minimum. It must have efficient wings and be made without rough edges.

Proper elevator adjustment is important to maximize performance in the flight of any airplane, including paper ones. (See p 36.) In aircraft of conventional configuration the horizontal stabilizer and the elevator provide a counterbalancing force compensating for the automatic downward pitching motion due to the center of gravity's location ahead of the center of lift. Furthermore, in all gliding flight, controlling pitch is especially important because it also controls airspeed. Airspeed, in turn, affects the glide ratio and overall performance of the plane. Every paper airplane has an optimum speed for a best glide ratio. This is its cruising speed. Adjusting a plane to fly at this speed is called *trimming for cruise*.

Gates Learjet

business jet

15

Building the Learjet

1

Photocopy the parts layouts for this model. Then cut out and prepare the pieces. (See the general instructions beginning on p 4.)

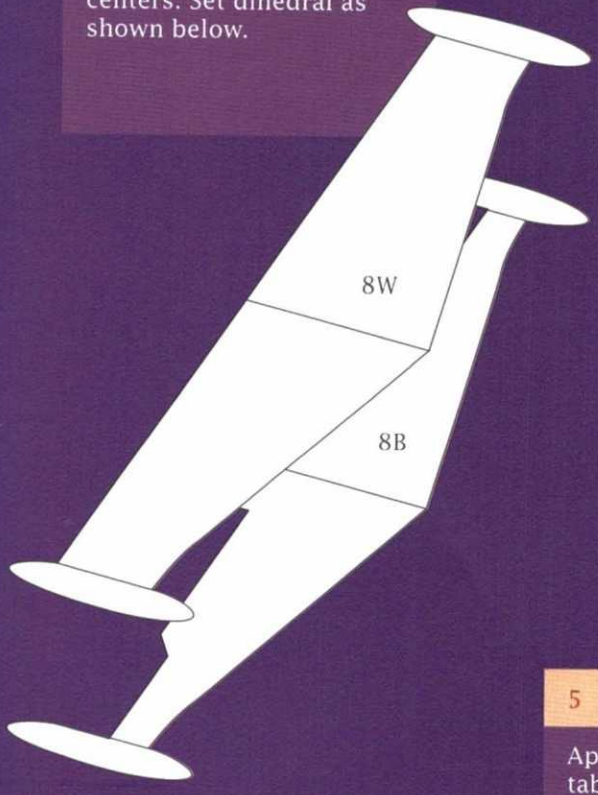
use wing opening slits and edges as positioning guides

2

Glue pieces 1F through 7R and 7L to build up fuselage layers, carefully aligning parts.

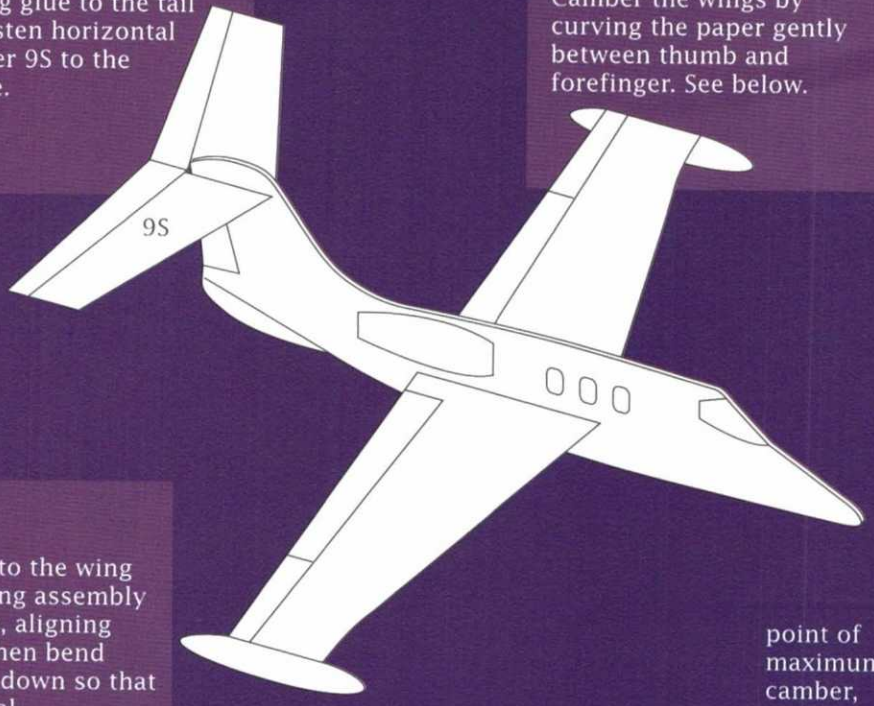
3

Glue piece 8B to the bottom of wing part 8W, aligning centers. Set dihedral as shown below.



4

Applying glue to the tail tabs, fasten horizontal stabilizer 9S to the fuselage.



5

Applying glue to the wing tabs, fasten wing assembly to the fuselage, aligning center lines. Then bend wing tip tanks down so that they are vertical.

6

Camber the wings by curving the paper gently between thumb and forefinger. See below.

WINGS 15°
HOR STAB 0°

point of maximum camber, 25-30% from front

CORRECT CAMBER

NOTE
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NOTE
CUT OUT PHOTOCOPY ONLY

HANDLING PAPER AIRPLANES

Pick up and hold paper airplanes by the nose, their sturdiest part. *Never* lift them by the wings or tail; this will distort their aerodynamic shape.

PREFLIGHT INSPECTION

After a paper plane is finished and the glue completely dried, do a preflight inspection and make any necessary adjustments.

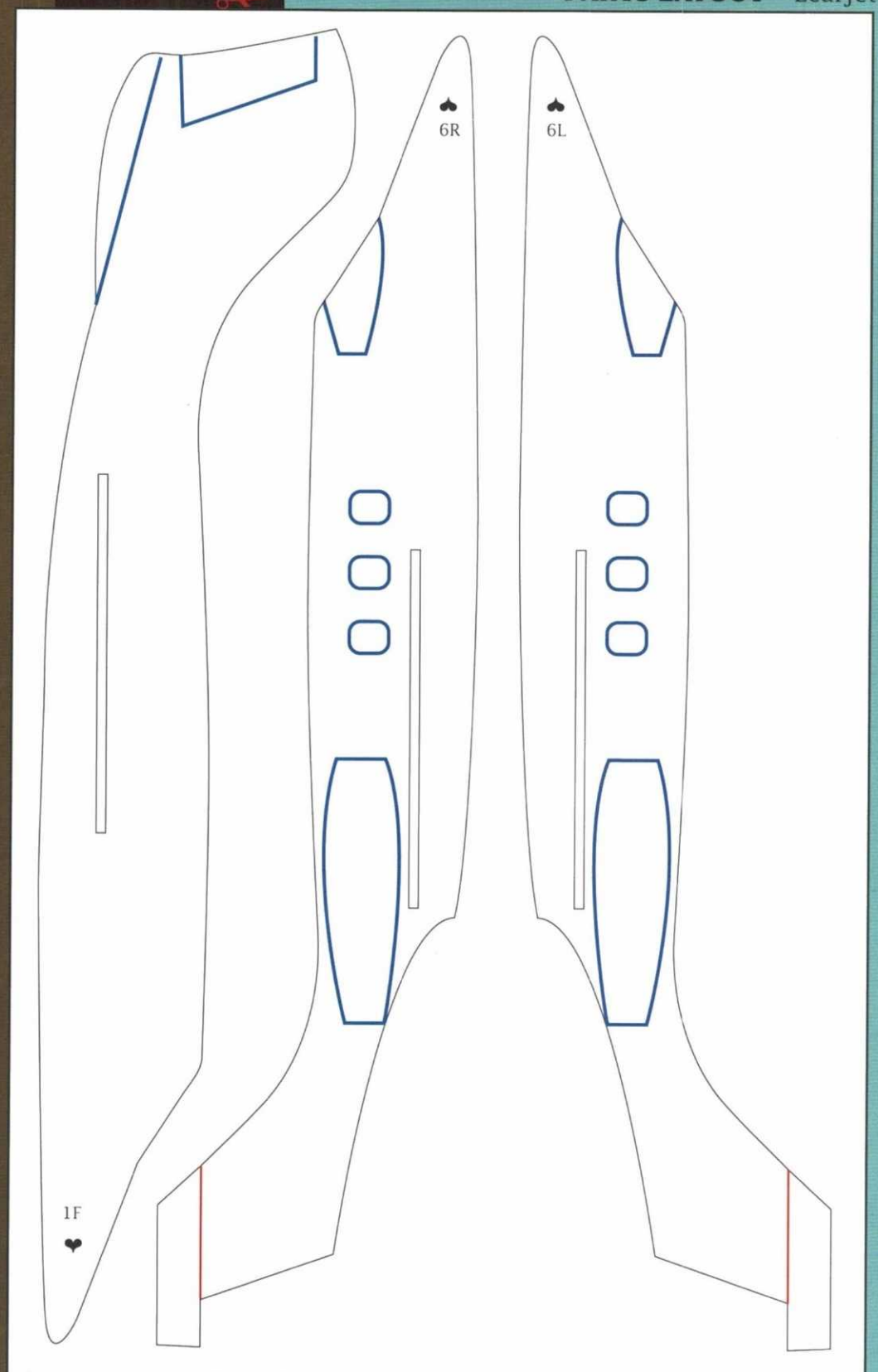
Examine the plane thoroughly from the front, back, top, bottom, and each side. Check for parts that appear bent or twisted. Correct any defects. Gently massage the paper to work out bends and twists. Each side must be *exactly* like the other — shape, size, camber, dihedral — a paper airplane must be symmetrical.

TEST FLIGHTS

The objective of test flights is to trim (adjust) the glider for straight and level flight at *its best speed.*

Hold the fuselage between thumb and forefinger just behind the plane's center of gravity. Throw it *gently* with a straight ahead motion (not as though it were a baseball). A paper plane flies best at only one speed. Throwing it too hard will cause it to climb sharply, stall, and dive to the ground, or do a complete loop. Once you have trimmed the plane for good flight performance, differ-

PARTS LAYOUT – Learjet



NOTE
- Cut on lines shown in black.
- Score lines in red.
- Use the blue lines as guides for adding details to the plane.
- ➧ Indicates the front edge of the piece.

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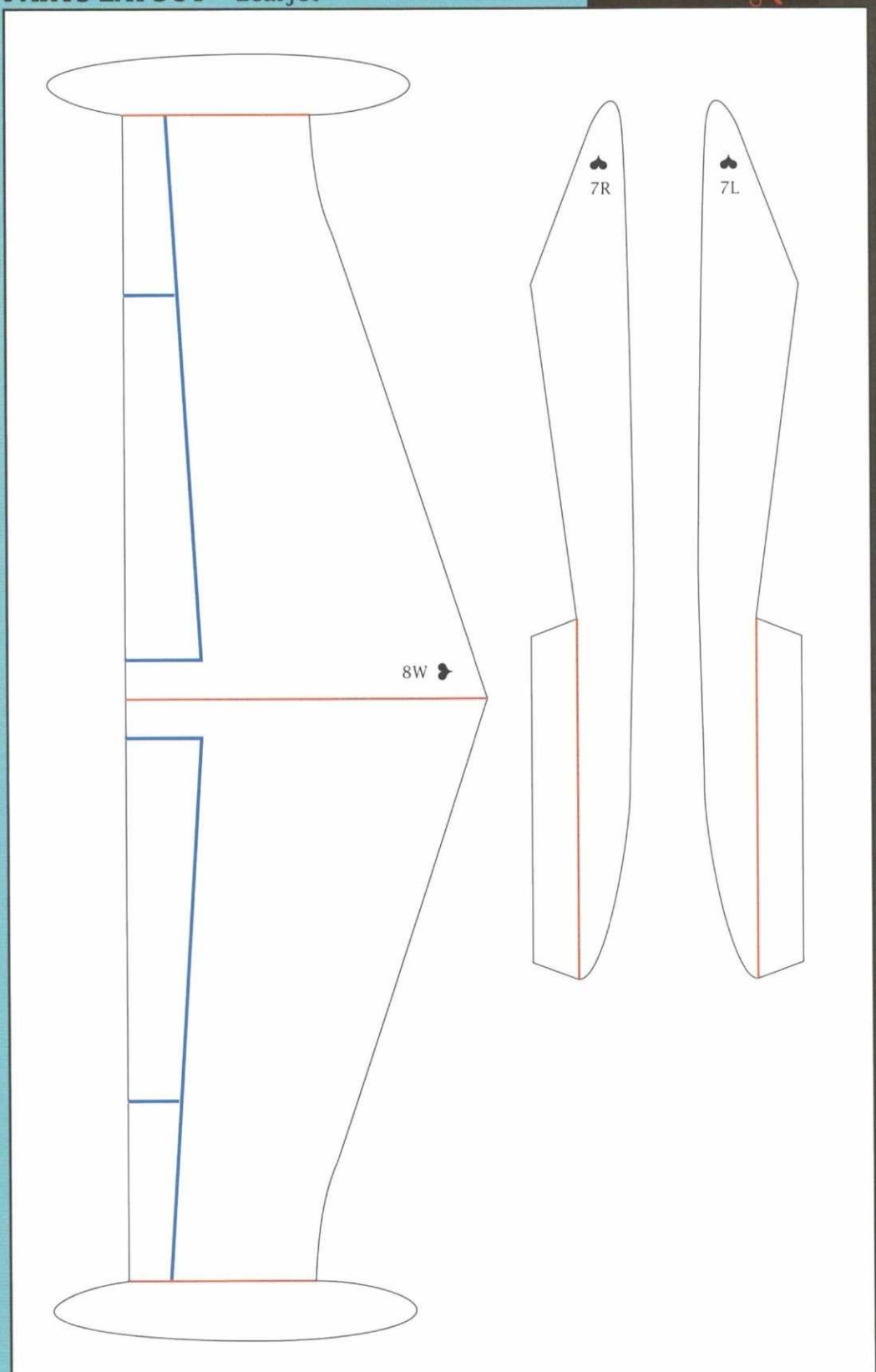

ent throwing techniques can be tried. Try to test fly in calm conditions so that each flight is more predictable.

Sometimes, on the very first flight, a paper plane is unbalanced in every way at the same time. Therefore it is necessary to separate the control functions in one's mind and deal with them one at a time.

To correct a dive the elevator needs adjusting by bending it up slightly to give positive trim. Continue making test flights concentrating on this one adjustment until this control input is correct. In normal gliding flight there should be slight positive elevator trim.

If a paper plane banks and turns in either direction it is always due to one wing producing more lift than the other. First make sure that the camber is *identical* in both wings along their entire lengths. If camber is slightly greater in one wing, that wing will produce more lift, causing it to rise — the plane will bank and turn in the opposite direction. Second, make sure that the wings are not twisted. The wingtip that is lower at the trailing edge (thereby having a greater angle of attack) will cause that wing to produce more lift, and it will rise — the plane will bank and turn in the opposite direction. Untwist the wings to correct this problem. Continue mak-

ing test flights concentrating on this adjustment until the wings are correct.

A slightly bent fuselage will also cause the plane to turn by yawing left or right. Make the fuselage as straight as possible. For a final correction adjust the rudder by bending it in the opposite direction to the turn.

If the plane climbs, loses speed, and pitches down sharply (stalls), the elevator needs to be bent down slightly. However, if this problem cannot be corrected without the elevator being bent down below the straight level, the airplane's center of gravity is too far back and additional ballast is needed in the nose. Glue additional layers of paper into the nose. Again, continue making test flights until this problem is corrected.

Continue to make test flights until the plane flies straight and level in a gentle glide.

EXTENDING THE FLIGHT

If a paper airplane is launched into the wind the increased relative airspeed would make the lightweight plane climb very steeply, and perhaps stall, and dive to the ground, or, if the elevator is bent up slightly, do a complete loop. When launched with the wind, wind speed is added to actual airspeed, increasing the ability to cover distance over the ground. But in a downwind launch the plane may stall if the wind is too

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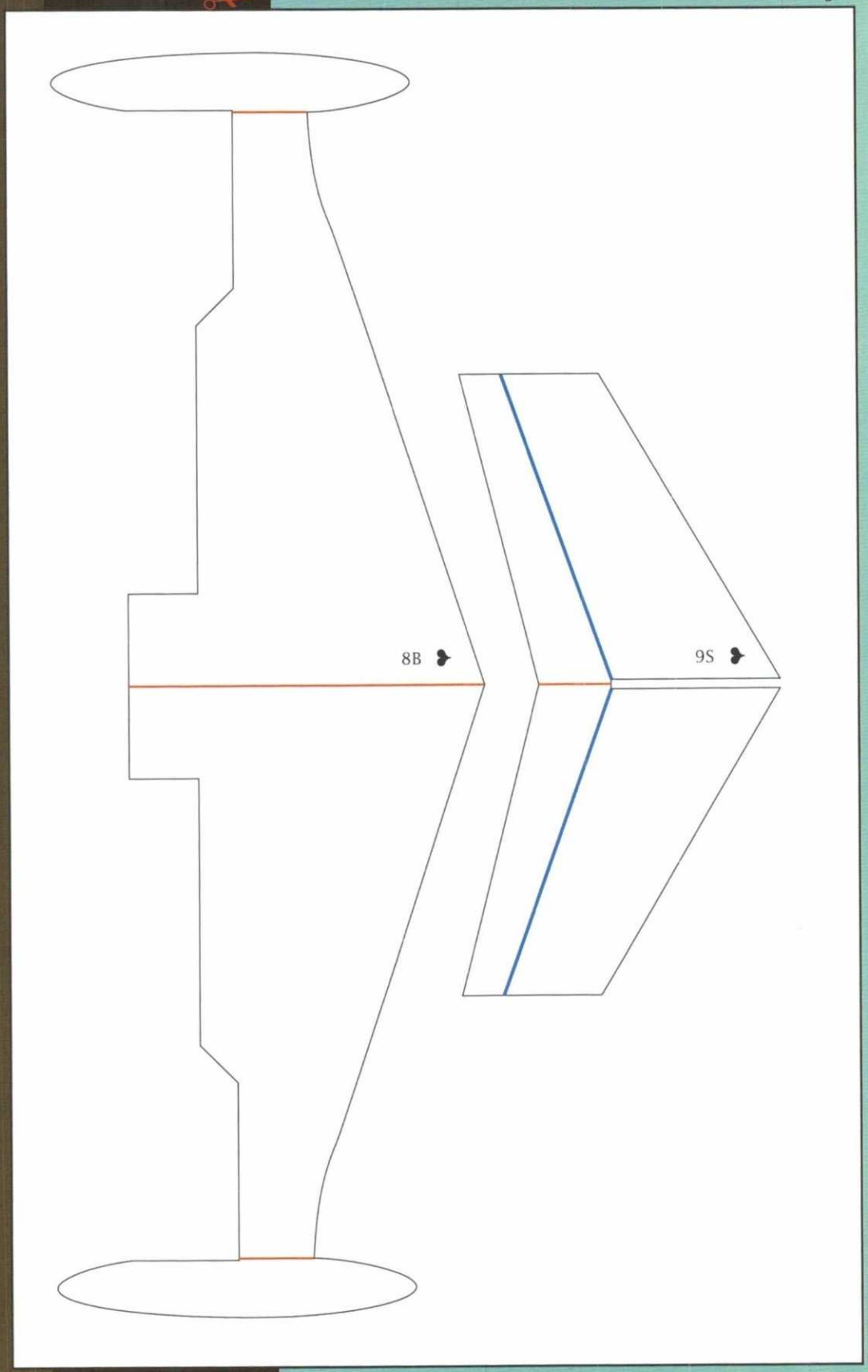

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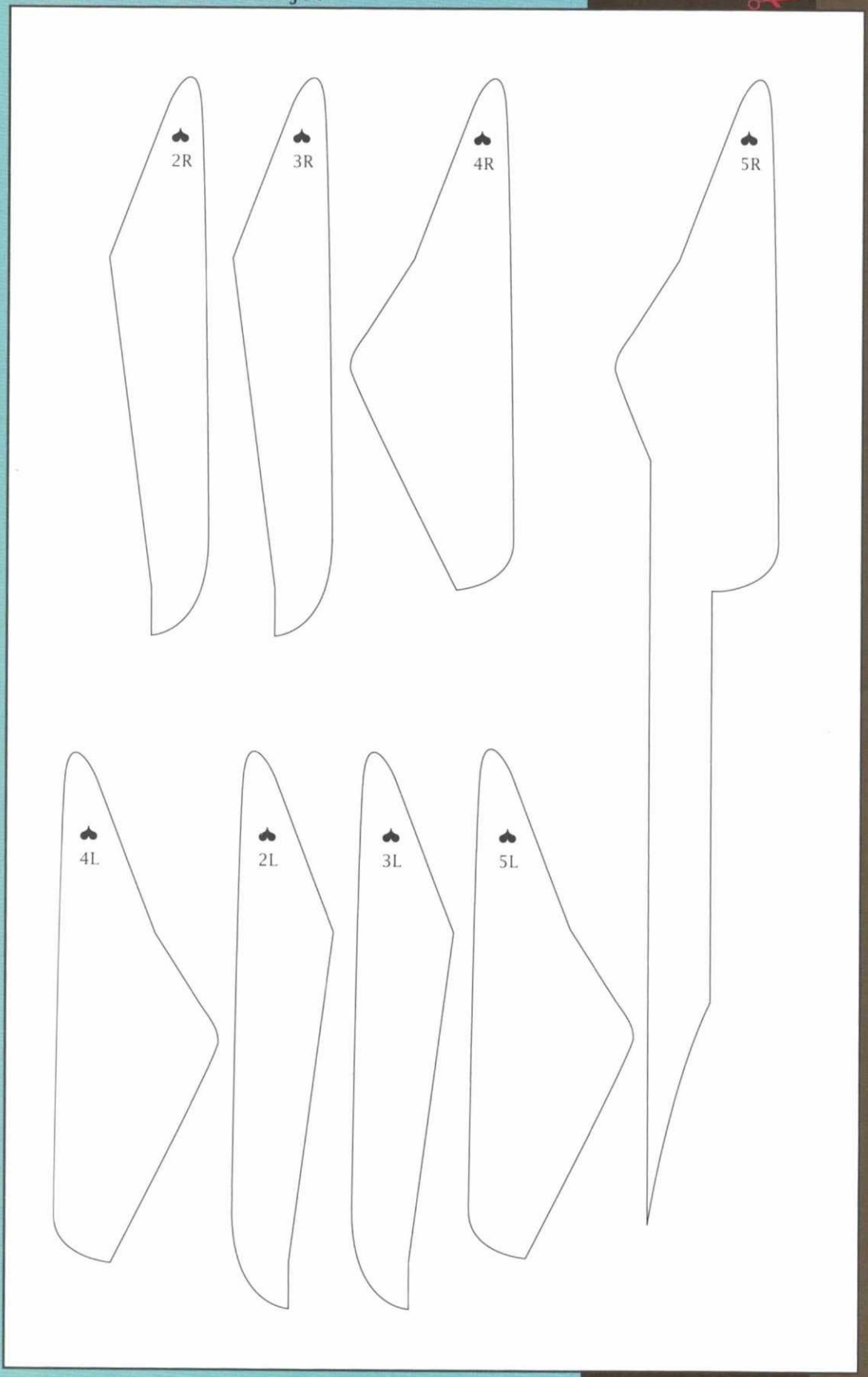


strong because of the decreased relative airspeed. To avoid these tendencies, launch the plane *across the wind*, letting it turn downwind gradually.

Another way to fly a paper plane is to begin the flight with a high launch. The plane should be trimmed for a gentle left or right turn. (If the pilot is right-handed, trim for a gentle turn to the left.) For making a left turn adjust the control surfaces. Make these trim adjustments in very slight increments until the desired turn rate is achieved.

Launch the plane in an inclined position with considerable force upward and away from your body (about 45 degrees), across the wind. It gains altitude from the force of the throw, but loses speed as it climbs. The dihedral causes the wings to level out. Once level, the left-handed trim banks the glider into a gentle turn downwind at the top of its climb. Because of the altitude gained by the high launch, the descent should be a good long glide.

Because paper is a relatively unstable material it may be necessary to readjust the planes after every few flights. Gusty wind conditions can make it impossible to fly such lightweight planes successfully.

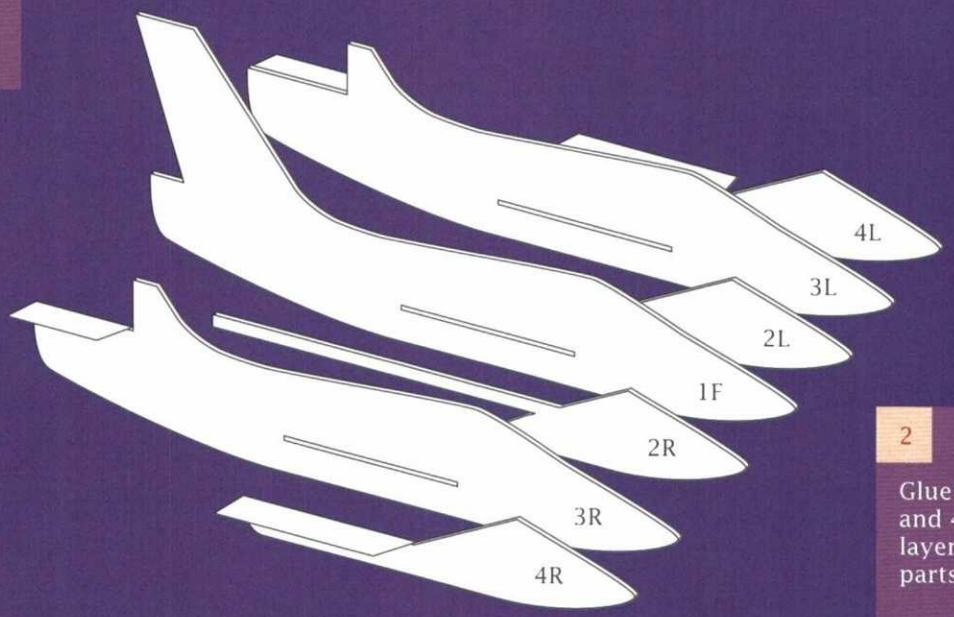
CMC Leopard
personal jet

16

Building the Leopard

1

Photocopy the parts layouts for this model. Then cut out and prepare the pieces. (See the general instructions beginning on p 4.)



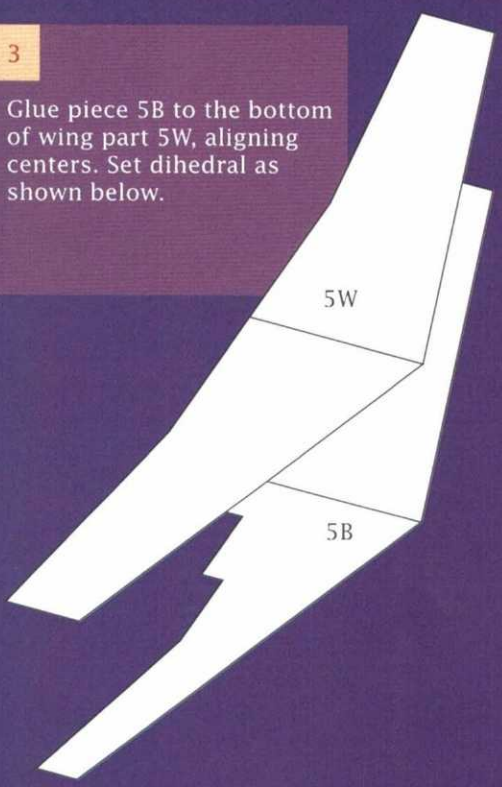
use wing opening slits and edges as positioning guides

2

Glue pieces 1F through 4R and 4L to build up fuselage layers, carefully aligning parts.

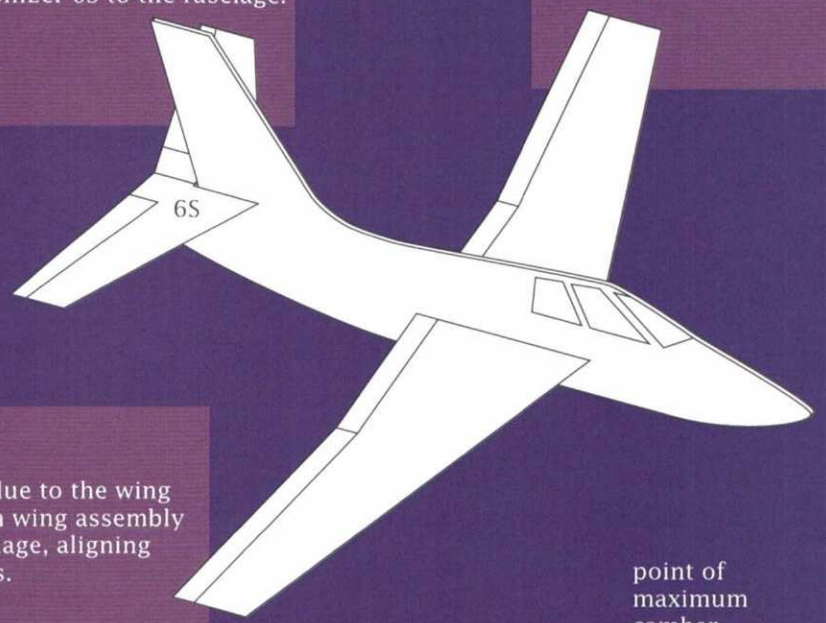
3

Glue piece 5B to the bottom of wing part 5W, aligning centers. Set dihedral as shown below.



4

Applying glue to the tail tabs, fasten horizontal stabilizer 6S to the fuselage.



6

Camber the wings by curving the paper gently between thumb and forefinger. See below.

5

Applying glue to the wing tabs, fasten wing assembly to the fuselage, aligning center lines.

WINGS 15°
HOR STAB -15°

point of maximum camber, 25-30% from front

CORRECT CAMBER

STORING THE PLANES

When carefully handled, these paper planes can last a long time. To keep them from becoming damaged or warped when not in use they need proper storage. One way is to hang them by the nose from a line using clothes pins.

By stringing the line inside a large cardboard box, a handy portable storage "hangar" can be made. (See below.)

FIGURE 12

A portable "hangar" consists of a line with clothes pins inside a cardboard box.

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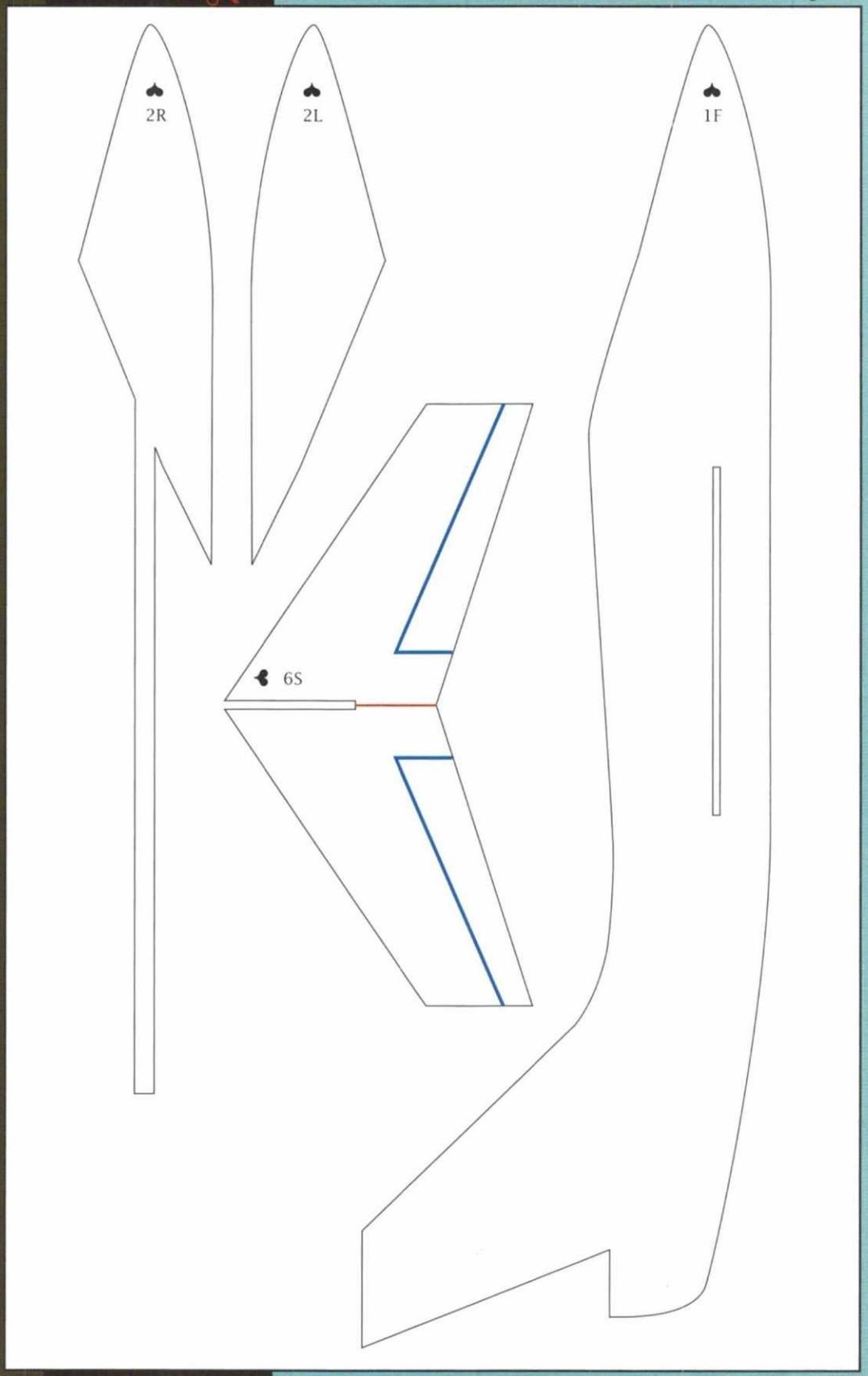
PARTS LAYOUT – Leopard



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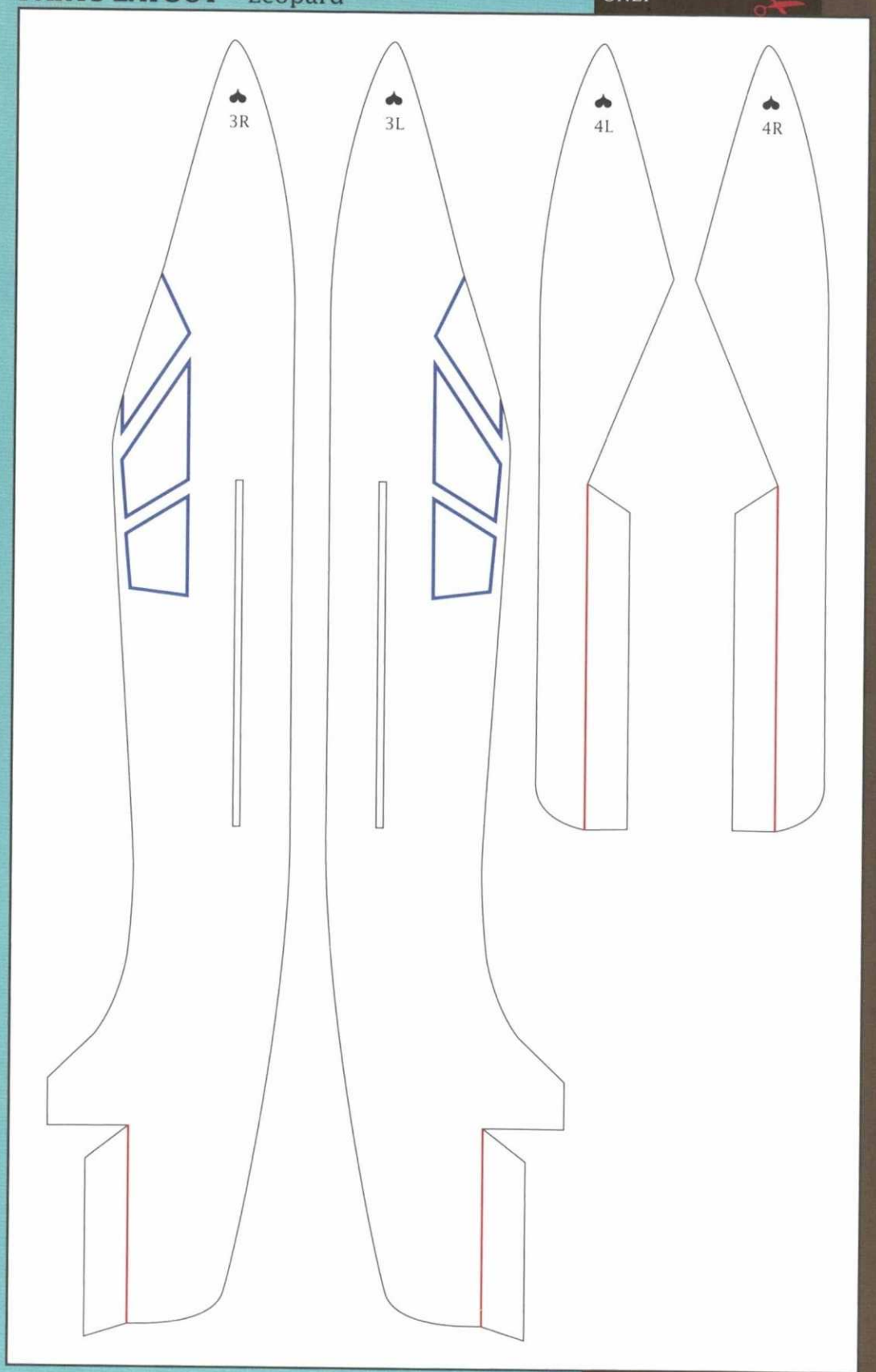


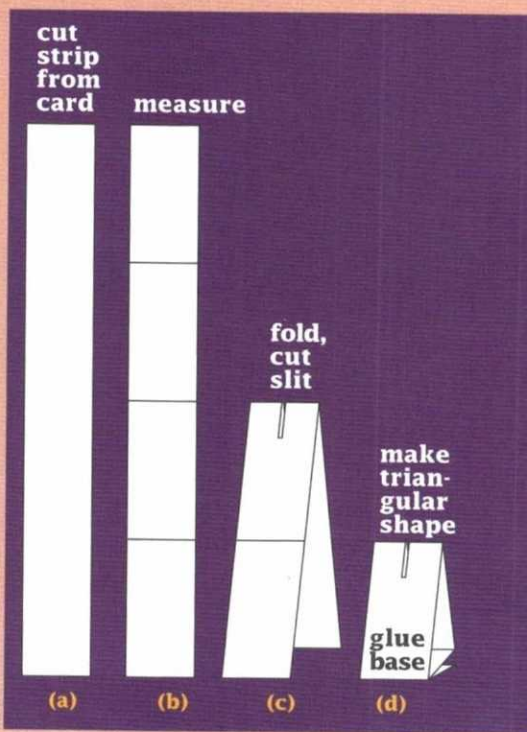
DISPLAYING THE PLANES

The paper jets make fine displays. Display mounts can be made from the same index card stock as the planes, according to the following steps.

a) Cut card into strip 1 in x 8 in (2.5cm x 20 cm).

b) Measure, dividing the strip into 4 equal sections.

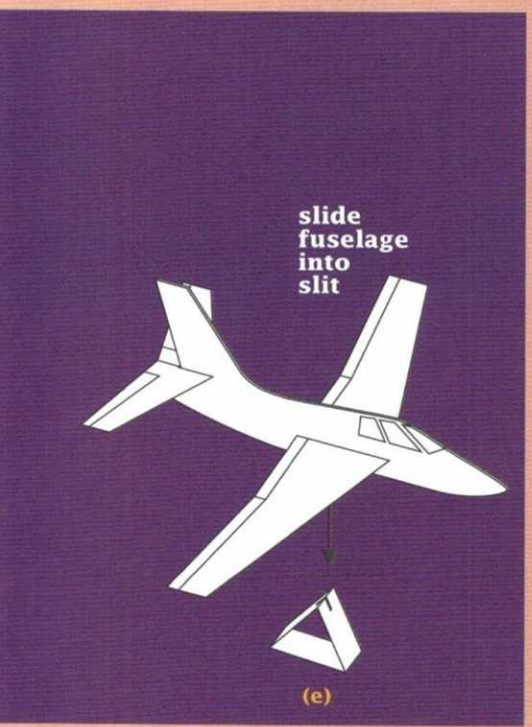
FIGURE 13
Making a display mount for the paper jet airplanes.



c) Fold strip in half. Cut a slit into the folded-over end.

d) Bend strip to form a triangular shape so that the two outer sections overlap to make a base.Glue the overlapping sections.

e) The plane's fuselage sits in the slit, balancing at its center of gravity. (See below.)



(e)

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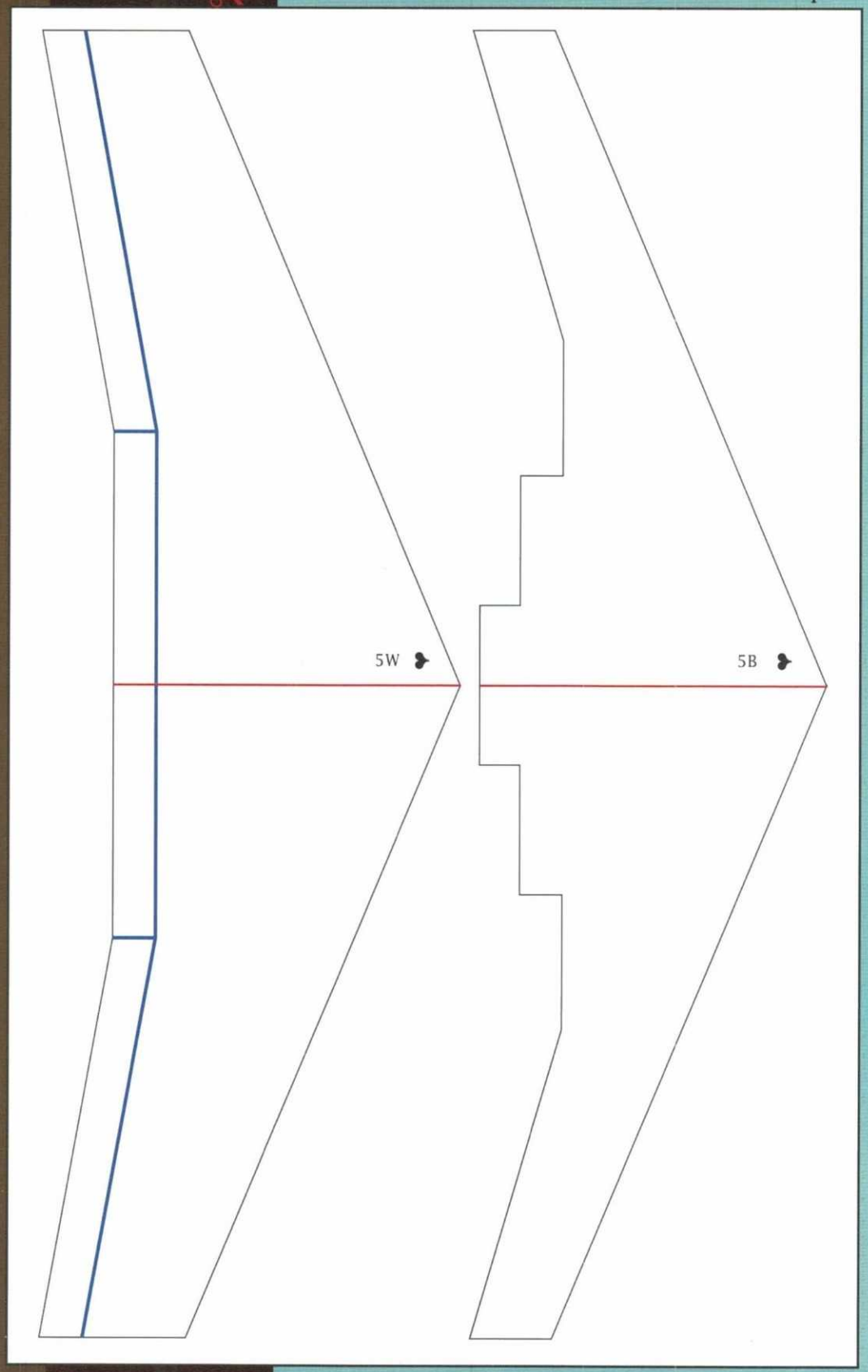

Concorde

Aeronautical terms

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Aspect ratio The length of a wing in relation to its width. A square has an aspect ratio of 1.

Ailerons Surfaces on the trailing edges of wings that control roll.

Airfoil A lift generating surface; a wing.

Airframe Those parts of an airplane (frame and skinned surfaces) that give it the ability to fly.

Angle of attack The downward slant, from front to back, of a wing to increase lift.

Attitude The roll, pitch, and yaw of an aircraft in flight, and the direction it is pointing in relation to the horizon.

Banking Raising the outside wing and lowering the inside wing during a turn.

Camber The convex curvature of the upper surface of a wing.

Center of gravity The point on an aircraft where its weight appears to be concentrated.

Center of lift The point on an aircraft where its lift appears to be concentrated.

Chord The measurement of a wing from front to back.

Control surfaces Small flat hinged surfaces on the trailing edges of wings and tail used to maintain equilibrium and maneuver an airplane.

Dihedral angle The upward slanting of wings away from the fuselage.

Drag The resistance of air on moving objects.

Elevator Control surface on the trailing edge of the horizontal stabilizer used to control pitch.

Fly-by-wire Aircraft control surfaces that operate electronically rather than mechanically.

Fuselage The body of an airplane.

Gravity The force of the earth keeping objects on the ground and giving them weight.

Horizontal stabilizer A flat horizontal surface directs the flow of air in aid of maintaining equilibrium.

Leading edge The front edge of an aircraft part.

Lift The force generated by the wings that counteracts the force of gravity.

Maneuver Skilfully making an airplane move in the correct manner and fly in the desired direction.

Pitch The rotation of an airplane causing its nose to go up or down.

Roll The rotation of an airplane causing the wingtips to rise or fall.

Rudder Control surface on the trailing edge of the vertical stabilizer used to control yaw.

Shockwave The pileup of sound waves around an object traveling at the speed of sound.

Sonic boom The explosive sound of the shockwave being generated by an aircraft passing by at supersonic speed.

Sonic speed (sound barrier) The speed at which sound waves move through the air.

Stall The condition that occurs when a wing's angle of attack is too great.

Strakes Small leading edge wing extensions at the wing root for added lift.

Streamlining Shaping an airframe so that air flowing around it creates the least amount of drag.

Supercruise An airplane flying at supersonic speed for an extended time.

Supersonic The speed of an object greater than the speed of sound.

Thermal barrier The amount of heat generated by drag that an airframe can withstand.

Thrust The force needed to move an airplane forward.

Trailing edge The back edge of an aircraft part.

Trim The adjustment of control surfaces so that an airplane in flight does not roll, pitch, or yaw.

Vertical stabilizer A flat vertical surface that directs the flow of air in aid of maintaining equilibrium.

Vortex The air that swirls in a circular manner behind each wingtip as air slips from the high pressure area below to the low pressure area above.

Wing loading The amount of weight a given area of wing is required to lift.

Wing span The measurement from wingtip to wingtip.

Yaw The rotation of an airplane causing its nose to go left or right.

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